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ABSTRACT

The booklet focuses on the use of the logical inductive strategy to teach problem solving skills to mildly retarded learners. An introductory section examines three research studies on interventions in the area of problem solving with the retarded learner and concludes, among other things, that mainstreaming has underscored the need for this population to have competent problem solving skills. The second section explores strategies and tactics, such as role strategies. Discovery type inductive strategies, especially the guided discovery strategy, in which the learner is provided some structure for the experience, are reviewed. The fourth section describes the logical inductive strategy, with emphasis on the three stages--mass, differentiation, and integration; and the five steps that comprise the strategy--labeling, detailing, inferring, predicting/verifying, and generalizing. The final section discusses methods of implementing the strategy and presents two simulated lessons and a chart illustrating the inductive problem solving sequence. (Author/PHR)

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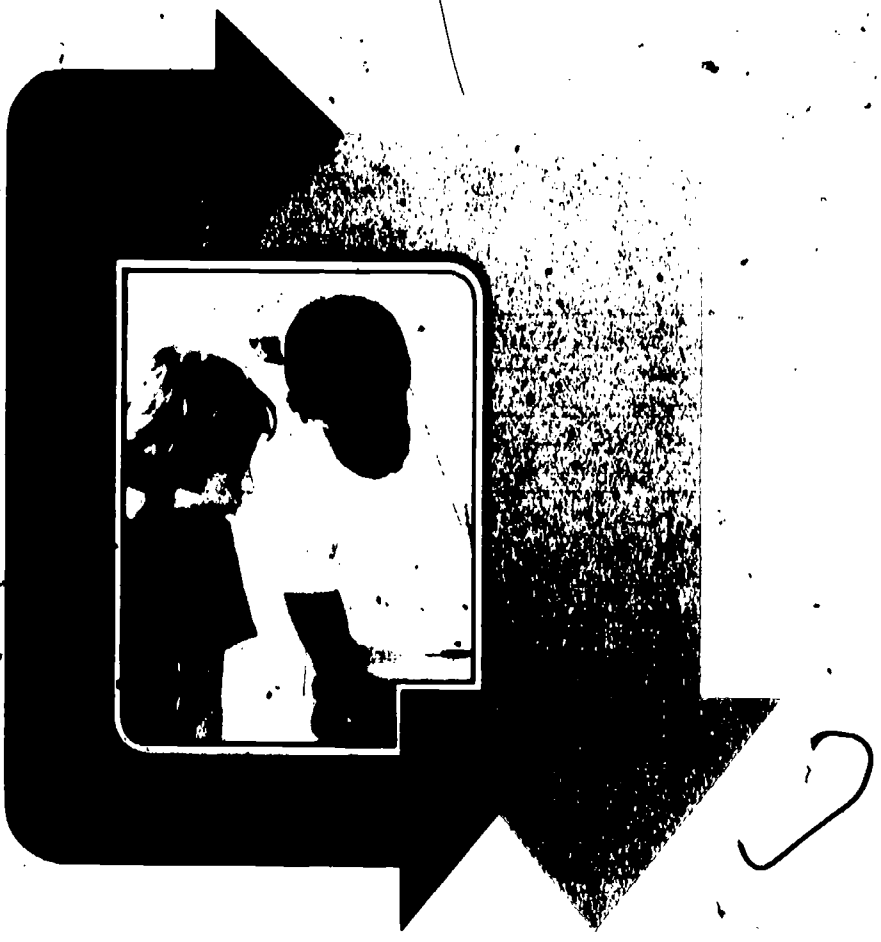
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REASONING ABILITY OF MILDLY RETARDED LEARNERS

Herbert Goldstein
Marjorie T. Goldstein

What Research and Experience Say to the Teacher of Exceptional Children



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What Research and Experience Say to the Teacher of Exceptional Children

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Preface

Mildly retarded learners are not as competent problem solvers as their nonhandicapped peers. Further, the more complex or abstract the problem, the greater the distinction seems to be. We need only compare the results of intelligence tests, tests of school achievement, and the social histories of retarded and nonhandicapped individuals to draw these conclusions.

Research and experience with retarded children and adults contributes a great deal to our understanding of why such marked differences in problem solving abilities occur. We have learned that there are many reasons why retarded persons know less than their nonhandicapped counterparts. Some say that they know less because some condition or set of conditions interferes with their ability to remember what they have learned. Thus, retarded individuals characteristically bring less information to bear on a problem. As a result, they often fail partially or totally to match their nonhandicapped peers in arriving at an acceptable solution to the problem.

Happily, there is considerable research underway in identifying conditions that interfere with learning and remembering what has been learned. Some researchers speculate that the conditions are *internal* to the individual; that the chemistry and central nervous system physiology of the individual have bearing on his or her problem solving ability. Others theorize that the conditions are *external* to the individual; that the way in which teachers and others organize and present content to mildly retarded learners influences their ability to retain information and, thus, to solve problems. There are signs that research along both of these lines is productive.

On a practical level, we as special educators need to be concerned with whether we are teaching mildly handicapped learners to solve problems efficiently and effectively. Two questions come to mind. First, are we teaching retarded learners what they need to know in order to cope with day to day problems? There are some who contend that there is a contradiction between what the followup studies indicate retarded people need to know and the curriculum that is offered them during their school years. This distinction becomes even more obvious as mildly retarded students are mainstreamed and involved mainly with academic instruction.

The second question is: Are we doing enough to help retarded students reason efficiently? Are we teaching students precise and orderly ways to process information that is fundamental to solving problems? There is no evidence to suggest that reasoning ability is genetically based. Since reasoning ability is an acquired skill, we are justified in assuming that reasoning, as a process, can be taught. We are also justified in thinking that strategies and tactics to improve reasoning ability can be taught.

Philosophers—epistomologists and psychologists in particular—are students of how humans reason, of how people assemble and process information so that they can understand, explain, and interact productively with their environments. The study of reasoning takes us from Dewey, Piaget, Bruner, and others, back to and beyond Socrates. We are all familiar with the Socratic method for inductive reasoning. Some teachers use this method in the course of instruction and some students learn how to use it as a problem solving process.

Theories of reasoning share two characteristics: They are logical and systematic in their organization. That is, the steps in reasoning strategies represent a consistent and predictable pattern; they have a rational relationship to each other and they follow a sequential order.

Departing from this operational view of reasoning, we take the position that the differences in peoples' reasoning abilities are a matter of how efficiently they are able to process information. All things being equal, for example, amount of information, perceptual abilities, personality, and so forth, individuals show differences in reasoning as a function of the orderlinesss and completeness of their approach to problem solving. At one extreme are those who have not acquired a discernible strategy for problem solving. Their attempts to reason through a problem appear random and they frequently approach the same kinds of problems in remarkably different ways. At the other extreme are those who have adopted a strategy so well structured that if is evident to an observer. In some cases, the process is so clear that an observer could almost predict the problem solver's next step. Mildly retarded individuals usually appear to be problem solvers of the first type.

This publication focuses on one important strategy to teach problem solving skills to mildly retarded learners: a logical inductive strategy.

The logical inductive strategy, like most other reasoning systems, evolved after empirical testing in practical settings. In this case, the strategy was refined over many years of use in classes for mildly retarded students, and is a key component of the Social Learning Curriculum (Goldstein, 1969), which was field tested and evaluated formatively in hundreds of special education classrooms throughout the United States. The logical inductive strategy has also been the subject of research, reported here, in which certain key assumptions underlying the strategy were tested.

We would like to express appreciation to Dr. I. Leon Smith and Dr. Sandra Greenberg for the research on the logical inductive strategy. Dr. Smith, in particular, provided the data and data analyses used in this publication. The *T*est of *H*ierarchies of *IN*ductive Knowledge (THINK) was designed by Drs. Smith and Greenberg; the initial use of the test to ascertain the systematic and logical attributes of the logical inductive strategy became the instrumentation for Dr. Greenberg's doctoral dissertation.

1 Introduction

The 1970's is commonly viewed as the decade when the civil rights of handicapped citizens gained national prominence. The litigation and legislation of the 1970's are often looked upon as the bill of rights of the handicapped and are seen as having evolved from the civil rights movement of the 1960's. However, the advocacy movement on behalf of handicapped individuals differs in important ways from other civil and human rights movements. For example, implicit in the civil rights movement was the notion that if attitudinal and economic barriers were removed, hitherto discriminated against people would be able to capitalize on social and economic opportunities. This assumption applies only to a limited segment of the handicapped population under a limited set of conditions.

Removing architectural barriers, for example, can broaden the social and physical world of physically handicapped persons insofar as they avail themselves of access. By contrast, access to the least restrictive environment in the schools, commonly accepted as membership in a regular class, does not necessarily hold a similar probability of success for educationally handicapped students. Access, by itself, does not guarantee successful participation.

The critical factor is the student's competence to become a functioning member of the regular class. Some students will be sufficiently competent to fit into the class quickly, while others will need accommodations if they are to be able to capitalize on their competence. A large majority of educationally handicapped students, however, will require intensive intervention in order to function productively in a regular class.

Often, competence in educational settings is equated with academic proficiency. However, successful adjustment to a regular class rarely hinges exclusively on academic competence, although this may be the criterion that guides many decisions made by teachers, administrators, and supportive staff (Mercer, 1973). The social-psychological nature of the classroom requires students to demonstrate academic, social, and personal competencies. In most cases, success or failure in the classroom depends on how well academic competence can be used as a means to solve personal and social problems. The way handicapped students get along with nonhandicapped classmates often determines the quality of their adjustment to a regular class.

There is a sizable group of students who, while minimally literate, are remarkably competent in regular classes. While this may appear to be a contradiction, it is not. Even though these students do not read at or near grade level, they continue to learn and to use important concepts and facts. Success for these students is often based on their ability to recognize the existence of a problem, to identify its parts, and to reason through to a solution that is consistent with the expectations and values of their teacher and classmates.

While the message of the civil and human rights movements was, in effect, "Remove the obstacles and we can make it on our own," handicapped individuals are, in large part, saying "Give us an education that is appropriate to our needs and more of us will demonstrate competence than you would ever believe." In the final analysis, then, the value of the legislation of the 1970's will be measured by the extent to which handicapped students are prepared to become competent participants in society; by the extent to which they are schooled for the skills they will need as adults. Comprehensive individualized education plans and administrative decisions based on compliance with mandates are important. By themselves, however, they contribute little to enhancing the competence of handicapped learners. The classroom teacher, who structures the content and methods of instruction, has the greatest role in contributing to the success of handicapped learners as competent problem solvers.

AVOIDING STEREOTYPES

Some educators may consider it a contradiction in terms to associate the development of reasoning abilities with certain handicapped students such as the mentally retarded. To them the perceived purpose of special education is to improve students' academic skills to enable them to move into regular classes. By concentrating on correcting learners' disabilities rather than focusing on their abilities, there is a tendency to deemphasize the development of reasoning skills. In the education of hearing impaired students for example, great effort is directed at ameliorating the disability through intensive instruction in communication and literacy skills. Far less effort is spent developing

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the kinds of reasoning abilities needed to make use of these skills in day to day situations. The position espoused in this book is that the development of academic skills and reasoning abilities are not mutually exclusive enterprises; teachers can promote academic and related skills while at the same time enhancing students' reasoning abilities.

According to Masland, Sarason, and Gladwin (1958), educators engage in much stereotyped thinking about the abilities of mildly retarded persons. One pervasive stereotype is that mildly retarded individuals have particular difficulty comprehending concepts and abstractions. They claim that this view of retarded learners reduces teachers' expectations about what such students can achieve. Further, they suggest that this leads teachers to rely on lectures, memorization, and drill as their teaching tactics. In so doing, teachers often fail to teach reasoning skills and, thus, do not offer the kinds of education the students require for success as adults in a society that rewards initiative and independence.

Individuals who have achieved the degree of independence necessary to succeed may be characterized by their abilities (a) to draw upon knowledge in some systematic way, and (b) to apply that knowledge to solving problems. The first presupposes that these individuals have been involved in learning experiences that will lead to the acquisition of relevant concepts and facts. The second presupposes that they have the ability to think through a problem, reach a conclusion or decision, evaluate the solution, and adjust their behavior accordingly, with little or no help from others.

STUDIES ON IMPROVING REASONING ABILITIES

Research on problem solving and reasoning skills is increasing, both in the number of studies conducted and in their diversity. One problem with such studies is that researchers rarely use the same terms to define their areas of inquiry. Some speak of reasoning, others of productive thinking, and still others use behavioral terms such as problem solving. It is not surprising, therefore, that Wolman (1973) found this to be one of the most chaotic research areas in psychology. In education, less attention has been given to research on problem solving, but what has been accomplished is enlightening. The work of such researchers as Taba, Parnes, Torrance, and Guilford has influenced teachers and administrators in elementary and secondary schools. In special education, researchers have borrowed from, or elaborated on, research done in the regular grades.

Tisdall (1962) studied mildly retarded children who participated in an experiment to compare the effectiveness of special and regular classes (Goldstein, Moss & Jordan, 1965). He noted that teachers in the special classes taught in a structured, inductive style while those in the regular classes used more eclectic teaching methods. Drawing on Tor-

rance's work, Tisdall proposed that mildly retarded children who participated in classroom activities emphasizing development of reasoning abilities and providing opportunities to practice these skills should, in Torrance's terms, exhibit more productive thinking ability. Tisdall's research supported this prediction.

Rouse (1965) took a different approach to examining relationships between teaching methods and 'the reasoning abilities' of mildly retarded children. Her contention was that these children could learn thinking tactics that would increase their reasoning or productive thinking abilities. She prepared 30 lessons to give students practice in "brainstorming" solutions to problems. The objectives of the lessons ranged from developing observation skills, to developing concepts of substitution, to improvising new uses for familiar objects. While these tactics were distributed through the 30 lessons, brainstorming appeared in most lessons. The teachers in the experimental classes used the specially designed lessons and encouraged the children to express original thoughts and actions. A control group used conventional teaching procedures in their classes.

Rouse's data supported her contention that mildly retarded children could learn tactics that would enhance their reasoning abilities. At the conclusion of her study, the children in the experimental group gained significantly in each of the measured areas of productive thinking. By contrast, the children in the control group barely held to their original performance levels.

In two somewhat related studies, Ross and Ross (1973) taught mildly retarded children a different, but still conventional, set of reasoning tactics using structured lessons. In the first study, the experimental children were encouraged to improve their abilities to listen to and understand a problem, to identify useful elements in solving a problem, to learn that some problems have more than one solution, and to develop self confidence in their problem solving abilities. The children were confronted with a variety of tactics for achieving their goals such as trading, combining assets, and effecting changes in situations. The control group experienced the same classroom conditions except that actual problem solving training was omitted. At the end of the study, the experimental and control groups were retested using a previously administered test of problem solving ability. The children in the experimental group were significantly superior in their ability to solve problems.

In the second study, using different groups of mildly retarded children, Ross and Ross focused on the development of planning skills for children in the experimental group. The training in planning involved having the children think through ways to solve a problem as a prelude to action. Members of the control group had the same general experiences as those in the experimental group except that they received no training in developing their planning skills. As in their other study, Ross and Ross found that the children in the experimental

group showed gains in planning skills far beyond that of the control group.

Conclusions

The three studies cited above are representative of work done using practical interventions with retarded learners in the area of problem solving or reasoning. While there are some limitations to these studies, their emphasis on structuring the interactions between teachers and students in the course of everyday classroom activities permits us to draw several practical conclusions.

The studies pointed up a fact that has been so taken for granted that it rarely gets the attention it deserves: *Differences in performance of retarded and nonhandicapped individuals are a matter of degree and not of kind.* In the case of reasoning, the studies helped to lay to rest the "all or none" distinctions between learners. They showed that *retarded children can learn what nonhandicapped children can learn.* They may not learn as much along the continuum of concepts and facts of a given topic, and they may not learn as quickly, but they can learn. Similarly, the studies confirm what special education teachers know from experience; namely, that within groups of handicapped students there are substantial differences in performance abilities. All three studies showed that some of the retarded children increased their reasoning abilities a great deal while others experienced moderate or little gain.

Does this mean that some children cannot learn what others can? The answer is "yes" if we persist in using with all children the formula for content and methods that was useful with the "gainers." Research tells us that certain tactics that promote learning and improve the retention of information are more effective with some children than they are with others. By observing how well certain children incorporate tactics into their problem solving procedures, teachers can pinpoint the tactics that are helpful for each child. This process can go a long way toward upgrading the achievement of an entire class.

The studies do not contradict the widely held notion that mildly retarded children have difficulty learning abstractions and concepts. However, they do provide evidence that *if a carefully organized effort is made to teach reasoning skills, many mildly retarded children can acquire concepts and deal with abstract rules and principles.*

If we teach retarded children in the same ways or by the same methods as nonhandicapped children, their reputations as poor problem solvers will probably remain intact. If, on the other hand, we subscribe to the view that individual differences are important and act on them to provide something special in special education for retarded learners, they can learn far more than has usually been expected of them.

A related insight into the reasoning ability of these children is that *mildly retarded learners can learn to reason in the ordinary course of classroom events if their experiences are carefully planned, continuous, concentrated, and relevant to their everyday lives.* In this sense, all three studies are remarkable for their everyday, commonsense approach; there were no heroics, magical incantations, elaborate and expensive equipment, or teams of specialist consultants.

REASONING IN COGNITIVE AND MOTOR LEARNING

The principle of individual differences applies to more than the teaching of concepts, rules, and principles. In the 1960's, O'Connor and Hermelin (1961) compared the performance of nonhandicapped and moderately retarded children on a simple motor learning task. In the predicted time, the nonhandicapped children learned to perform the task while the members of the retarded group seemingly learned nothing. Instead of terminating the study at that point, O'Connor had the retarded children continue their efforts. After more practice, the moderately retarded children began to show signs of learning. Although they required more than three times as much practice to begin learning, once that stage was reached, their rate of learning soon increased to match that of the nonhandicapped group.

At about the same time, Clarke and Clarke (1962) were having remarkable success teaching rather complex motor skills to moderately retarded adults. They structured each step and altered procedures to accommodate the different characteristics of the learners. In short order, these people were working in sheltered settings and at jobs far more complex than the usual envelope stuffing or counting and bagging tasks. It was not unusual to enter a Senior Training Centre in England and find retarded adults using power tools and welding and soldering equipment, and performing intricate assembly tasks. In general, they learned these skills more slowly than most nonhandicapped persons, and there were marked variations in the rate and quality of the retarded persons' work.

More recently, similar work has been done with severely retarded individuals. Gold (1972) and others have shown that many severely retarded youths and adults can learn complicated assembly tasks. Behavioral psychologists have successfully taught a broad range of self care skills and social behaviors, previously considered impossible, to severely and profoundly retarded persons.

Together, these studies and experiences tell us that *attending to individual differences in cognitive and motor abilities can help teachers structure learning experiences in ways that will be most helpful to students.* For example, before we say that Mabel cannot learn her telephone number because she can't remember it from one day to the next, we ought to examine what we've been doing. Have we been teaching this skill to Mabel in the same way that we taught it to

Irving, JoAnn, and Clyde. Who quickly succeeded? Did we give Mabel more time, more practice, more encouragement? Have we tried to find a mnemonic clue that Mabel could use effectively? Have we, perhaps, confronted Mabel with more information than she could handle? Do we expect her to learn the same amount of content that we prescribed for the "remembrerers"? Mabel's *seeming* inability to remember may be more a function of the way she is being taught than a symptom of retardation. It is important that we determine the former before we accept the latter as a fact of life.

The discussion of motor learning within the context of reasoning is not as much a diversion as it may seem. While it is customary to view research that deals with motor learning and cognitive learning as separate sets of actions, in real life they are interdependent. The fact is that a certain amount of reasoning enters into the learning of motor tasks. Gold's students, for example, could not learn to assemble anything as complex as a bicycle brake without learning how to distinguish between the parts, associate which part attaches to which, recognize when a subassembly was wrong, and remember the sequence of events from one day to the next. All of these are cognitive behaviors and are important elements in reasoning performance even though they are embedded in motor performance.

As with the earlier studies of problem solving tactics, these studies of motor performance further confirm that individuals differ in the degree rather than the kind of performance of which they are capable; that individuals vary widely in their capabilities. Few of Gold's students were as proficient in verbal ability or in solving sociopersonal problems as they were in performing certain well taught motor tasks. At the other extreme, there are individuals who are outstanding in their ability to solve complex problems but who are, at the same time, motorically incompetent. They whiz through the *Times* crossword puzzle and file their income taxes accurately and on time, but do all sorts of damage to themselves and their surroundings in the course of hanging a picture.

Task Analysis

One need only observe the Clarkes, Gold, O'Connor, and others in action to find that the key to their successful teaching of motor tasks is in the way that the tasks are planned and structured. Task analysis is the first stage. It allows the teacher to know what has to be done, in sequence, one step at a time. Sequences of events are then planned in logical and psychologically based steps. The distance between steps and the amount of content to be mastered at each step are tailored to the characteristics of each learner. Since the steps are flexible, a teacher may alter them if first estimates of a student's abilities are in error. Thus, if the amount to be learned at each step proves to be too much for a student to manage successfully, the amount is quickly

reduced and what was originally planned as five sequential steps is increased to seven or, if necessary, ten steps. The opposite is true when a student's abilities have been underestimated.

Rewards

The success factors, like the teaching plans, are carefully structured in the accomplishment of the motor tasks. Whether they are called reinforcements, rewards, contingencies, or satisfiers, they are an important part of the teaching enterprise. The nature of the reward is far less important than how much meaning it has for the individual learner. Some learners may be fully satisfied by the results of their efforts; they do not need the approval or confirmation of others. Other learners may require nothing more than the good feeling they get when someone important to them shows approval of their efforts. Still others may prefer a privilege or concession; time to engage in a pleasurable activity. Others may be impressed by some kind of material reward, such as a sweet, a coin, or a plaything.

Heber (1959) had two groups of retarded persons rank an array of prizes according to which each preferred most to least. Both groups were given the same motor task to perform. One group was promised the prize they most preferred and the other group was promised their least preferred prize. Predictably, those who were promised the prize they preferred most worked more rapidly than those promised the prize they valued least. When the conditions were reversed, the fast workers reduced their rate of work while the formerly slow group speeded up considerably.

The important fact to keep in mind is that while teachers may feel they "know what is best" for students and should therefore determine what rewards are appropriate, it is what the individual student values or needs most that will be the most powerful reward. At home, children make this message clear and befuddle their parents when they discard an expensive toy and play instead with the box it came in.

While improvements in motor performance are far more visible than improvements in cognitive performance, this does not justify the view that motor and cognitive learning are separate enterprises, each with its own discrete set of strategies and tactics. Instead, the fact that they are often interrelated in problem solving suggests that much can be learned from studies in motor learning about tactics that can be applied to the teaching of cognitive skills.

SUMMARY OF RESEARCH ON REASONING

Research and experience suggest the following points about the reasoning abilities of mildly retarded students.

1. While mildly retarded children and adults have always needed the ability to reason in order to solve everyday problems, this need has

been dramatically underscored by changes in school and community situations brought on by litigation and legislation. Successful mainstreaming, for example, does not depend exclusively on academic skills and proficiencies. Mildly retarded students in regular classes need to participate in a broad range of activities requiring collaboration and cooperation with their classmates. Their ability to do so successfully often depends on how well they can enter into problem solving situations and classroom activities that require more than the ability to read and reckon.

2. While it is important that these students learn academic skills to the best of their abilities, it is equally important that they learn tactics to help them capitalize on their reasoning ability. Studies show that mildly retarded students are responsive to instruction in tactics that improve reasoning ability if instruction is consistent, orderly, and matched to individual students' learning styles.
3. Reasoning ability is not confined to cognitive activities. Motor learning requires reasoning ability, and the procedures that teachers use to promote motor learning are often appropriate in teaching reasoning skills. Among these are task analysis, prescription of the amount of learning at each step, constant assessment of student progress and revision of the steps as needed, and appropriate reinforcement using whatever has value for the learner.
4. Mildly retarded children, like all children, have acquired whatever reasoning ability they possess. What often sets them apart from other children are their limitations and not their inability to perform. Thus, having acquired or learned whatever reasoning abilities they exhibit, they should be able to improve them if they are taught how to employ the necessary strategies and tactics to do so.

2 Strategies and Tactics

To some degree everyone thinks and everyone reasons. Since reasoning is an acquired skill, it follows that people can be taught to improve their reasoning abilities. Research has shown that most retarded students improve their reasoning skills if these skills are taught in systematic and logical ways, and if the strategies and tactics used are consistent with sound principles of learning. Since the terms "strategies" and "tactics" are prominent in the educational lexicon, it is important to distinguish between them.

Strategies are formulas for reasoning that are generalizable across broad categories of problem solving behaviors. Without intending to oversimplify the extremely complex nature of strategies, the position taken in this monograph is that all problem solving can be subsumed under three types of strategies: rote, inductive, and deductive. Tactics, by contrast, are viewed as individual procedures that are used to meet specific teaching objectives. The major attribute common to strategies and tactics is that they both contribute to problem solving. The difference between them is seen in the scope of their application.

STRATEGIES

Rote Strategies

Using rote strategies, problems are solved by way of remembered information. This type of problem solving appears to be almost mechanical: Having learned certain facts, we are able to apply them without obvious thought. For example, the commuter, asked the cost of travel

by a stranger, quickly states the correct amount. The history student names the thirteen original colonies at his teacher's request, and the woodworker, having inserted the screw, twists the screwdriver in a clockwise direction in order to set it firmly.

The keys to applying rote strategies are (a) the scope or number of facts learned and their relevance to day to day problem solving, (b) the quality of learning and retention of the facts; and (c) the accuracy of the problem solver's perception of the problem, and his or her ability to draw on relevant information.

Inductive Strategies

Inductive strategies make use of both facts and concepts. As reasoning procedures, inductive strategies proceed from the specific to the general. In practical terms, the process begins with the *acquisition* of facts and concepts, proceeds to the *assembly* of facts and concepts to arrive at a *generalization* (rule or principle), and terminates with the *application* of the generalization to a broader set of problems.

To illustrate, let us assume that we have to get from one end of Manhattan to the other, but we are strangers visiting New York City for the first time. We could not be expected to know much about traffic or distance or how these relate to travel time. All we start with is the knowledge that we may choose either walking, or taking a bus, subway, or taxi. We also know that we do not have an infinite amount of either time or money, so we put walking and taxis aside as options. Now we look at buses as an alternative; among other facts, we know that buses are surface vehicles. As such, they could get involved in all kinds of traffic slowdowns. Even if that didn't happen, they must contend with traffic lights and controls. Subways, by virtue of their site of transport, are not prey to such delays. We don't know if the cost of a subway and bus ride is the same so we ask a passing New Yorker. He informs us that the fare is the same. We infer from the information we have collected that the subway is our best bet, and we decide to take it. When we reach our destination, we verify with our friends that our choice was the better one since the bus, we are informed, would have taken considerably more time.

This illustration of inductive thinking follows a logical sequence in which the individual collects the information needed to solve the problem, acts on a decision, and then verifies that the decision was appropriate. In Chapter V, an inductive teaching strategy is applied to this same problem.

The success or failure of inductive strategies is determined by two interrelated conditions. First, the problem and its elements—facts and concepts—must be within the learner's range of knowledge; they must be in the learner's knowledge bank. The individual must be able to recognize a problem, and must have the language and prior experiences that constitute problem solving tools. Second, the steps in

the problem solving process need to be developed so that they build upon each other in a logical sequence; each added "bit" of learning should expand the learner's knowledge bank. The use of a random progression of steps can defeat the objectives of problem solving.

The developmental progression of inductive strategies is helical rather than linear. Since we are continuously learning new facts and concepts, we are constantly adding to our knowledge-banks. These newly learned facts and concepts help us to arrive at "new" rules and principles. As we increase our repertoire of rules and principles, we also increase the possibility that we will be able to solve problems using deductive strategies.

Deductive Strategies

Deductive strategies are procedurally the opposite of inductive strategies, since they proceed from the general to the specific. Using a deductive strategy, once the nature of the problem is understood, the learner selects from a repertoire of rules and principles the one (or more) that applies and uses it to solve the problem. For example, having learned inductively the rules and principles for "getting along with others" in the classroom, the student can apply them toward the same end on the playground, or in a classroom in another school, or at a scout meeting. The New York City travel example can be used to illustrate this point. Having learned that the subway is generally a fast, reliable, and inexpensive way to travel, if we found ourselves in San Francisco and wanted to go from lower Market Street to the Mission District, we might quickly deduce that BART will get us there faster than the bus.

Clearly, deductive reasoning is a more "mature" behavior than inductive reasoning, since it can only be applied after certain rules and principles have been thoroughly learned. Only then can they be drawn upon easily to solve problems in what appears to be an almost automatic way.

CHOOSING AND USING THE STRATEGIES

The three strategies may be viewed as formulas for solving problems in all academic areas, and in personal and interpersonal areas as well. They may be used regardless of the content that forms the basis of a problem. With this in mind, our efficiency and effectiveness as problem solvers are determined by the extent to which we approach problems in a logical and systematic way. Similarly, the extent to which we teach mildly handicapped students to reason in logical and systematic ways will determine, in large part, how successful they are as problem solvers.

The preceding discussion stressed how strategies relate to reasoning as a problem solving behavior without clarifying the role of teachers in this process. No matter how teaching roles are defined or described, it

is evident that teaching itself is a problem solving behavior. Teachers must set objectives for students' learning. They must decide what they will teach to meet the objectives, and what materials they will use to promote learning. Teachers must also decide how students will participate in the learning experience. Finally, teachers must assess whether or not the objectives they have set have been reached. These are recurring sets of decisions that must be made by teachers.

Not the least of these decisions is determining which teaching strategy will contribute most to attaining a particular objective. Is it the teacher's objective that the students will learn color names? Clearly, a rote teaching strategy is indicated. Does the teacher want the students to conceptualize the principle of place value as a preliminary step to learning "carrying" and "borrowing"? The word *conceptualize* eliminates consideration of using a rote strategy. Is a new principle to be learned? Is the goal to have the students generalize the principle? If so, an inductive teaching strategy will serve best. Is the teacher's objective to have the students expand their knowledge about their community? Since expanding means enlarging on already learned rules and principles, a deductive teaching strategy will probably be most effective.

Teachers are concerned with more than simply delivering instruction. They are also sensitive to such factors as their students' motivation to learn, self concept, and the like. The question arises of how teaching behavior affects these factors. According to Flanders (1968) and others, teachers are probably far more powerful models for students' behavior than they realize. This being the case, it is not unlikely that teachers influence students' feelings about learning and about themselves as learners by the way they relate to students in the course of instruction. How they relate is readily apparent in the behaviors typical of each teaching strategy.

In rote teaching, for example, the teacher decides what is to be learned, tells the students what is to be learned, prescribes practice, elicits evidence of learning, and tells students when they are correct or incorrect. Roles are clear; the teacher is the actor and students are reactors. There is little opportunity for students to participate or to think independently.

Inductive and deductive teaching strategies, on the other hand, provide a different set of roles for both teacher and students. Often, the teacher can so arrange experiences that students sense the problem without overt teacher help. Instead of telling students what needs to be learned, the teacher elicits this information or participates with the students in generating it in order to solve the problem. Students have opportunities to promote their own learning and to participate at every step in the problem solving process. They may also participate in evaluating the quality of their solutions and in generalizing rules or principles based on what they have learned. In other words, the teacher sets the stage and evokes responses from the students rather than telling them what to do. Students can, if they wish, respond or listen to the responses of their classmates. They may, in time, learn

that responding yields dual rewards; one for responding and participating, and another according to the appropriateness of the response. Even if students respond incorrectly, they receive approbation for having tried.

Shy, withdrawn, or failure avoiding students are only in the limelight when the teacher feels they are ready. In the meantime, they are observing the interactions between the teacher and more responsive classmates and are in the midst of learning situations rather than being isolated, as is the case in most teacher directed transactions.

Does this mean that rote teaching is "bad" and inductive and deductive teaching are "good"? Not at all. As noted earlier, rote teaching is most effective when the learning and retention of facts are the objectives. Inductive and deductive teaching are most effective when learning, retention, transfer, and generalization are the objectives. What is "good," then, is selecting teaching strategies that are consistent with the instructional objectives to be mastered and that will get the job done efficiently and effectively.

Of the three teaching strategies discussed, the focus here will be on inductive teaching for the following reasons: (a) teachers are already well versed in rote teaching strategies, and (b) studies on the reasoning abilities of mildly retarded students indicate that these students are at a "rule and principle accumulating stage" for most of their school years. Thus, experiences with inductive teaching and learning are needed from school entering age forward.

However, before the discussion of inductive teaching strategies proceeds, the use of tactics as teaching and thinking tools will be discussed briefly.

TACTICS

Teachers and researchers have had more experience with teaching and problem solving tactics than with strategies. Recent publications reporting on studies of teaching effectiveness (Peterson and Walberg, 1979) and on teaching styles (Gage, 1978) deal more with tactics used in teaching than with any other aspect of the educational process.

While the literature describes a broad range of tactics including classroom management, psychosocial development, and problem solving tactics, this discussion will be limited to problem solving tactics used in prior research because of their demonstrated influence on reasoning. Only a publication devoted to the rich and productive array of tactics available to teachers could begin to do justice to this topic.

Earlier, strategies were distinguished from tactics by the statement that strategies are formulas for approaching problems whose results yield rules or principles that may then be applied to a whole class of similar problems. It was also noted that strategies are situation free and content free; they may be used in every area of inquiry. Tactics are more situation specific. Thus, the teacher must select the tactic

or tactics to be used according to the nature of the students' abilities and the problem to be solved.

Teachers must be careful observers of the problem solving tactics used by their students. Studies have shown that some retarded students have problems *attending* and *observing*. Some display limited abilities to *classify* and *categorize* facts while others have never learned way to *substitute*, *trade*, or *exchange* things that they have for things that they want. There is considerable research to support the notion that these tactics can be learned, to some degree, by most retarded learners. Once basic tactics are learned, the students are ready to learn more complex tactics and the conditions for their use, and to evaluate their effectiveness.

Examples of more complex tactics include brainstorming and planning. Brainstorming was a tactic used by Ross and Ross (1973) to promote reasoning abilities of mildly retarded children. This tactic is effective when the objective is to discover new ideas or new ways to cope with an issue or problem, particularly when it is clear that conventional techniques are ineffective, inappropriate, or, for some reason, undesirable. A difficulty in using brainstorming tactics for problem solving is in reaching consensus on which of the many fresh ideas will be adopted. Further, brainstorming is not the ideal tactic in all situations. Knowing *when* to brainstorm is critical. This tactic would not be indicated, for example, to solve crisis problems requiring immediate and direct action. It is important, then, not only to teach a problem solving tactic thoroughly, but to link the tactic to the appropriate conditions for its use.

Parenthetically, brainstorming is an especially difficult activity for some retarded children. Some researchers feel that this is because retarded children are not very creative. However, Tisdall's (1962) study showed that retarded students matched the performance of their nonhandicapped peers in creative thinking. To disregard this type of information in favor of retaining stereotypes of retarded persons is to run the risk of underestimating their abilities and of lowering expectations for their performance.

Planning is another important tactic that contributes to problem solving. All planning requires the individual to take the time, before acting, to think through a problem, taking into account what might happen at every step, and to anticipate the outcomes of different sets of actions. Planning may be applied to problems that have either a specific desired result or an array of acceptable alternatives. Examples of the former include planning for a picnic or how to raise funds for the United Way. Examples of the latter include planning for a vacation or, more dramatically, for retirement. The quality of planning often corresponds directly with the quality of the result.

Learning how, why, and when to plan needs to be viewed as a preliminary step to action if it is to be more than an intellectual exercise. Experience shows that simply knowing about planning will not, in itself, lead to better problem solving. Estate planners are among

those who die intestate, the Internal Revenue Service office has its share of tax specialists anxiously milling around its offices on April 15, and large numbers of intelligent people may be found in line at the vehicle inspection station on expiration day.

The key to using planning tactics with mildly handicapped youngsters is to teach them to take the time to think through a problem in an orderly way before they act. However, if lessons on planning are to be effective, they must provide opportunities for students to act on their plans, to evaluate their effectiveness, and to discuss what changes, if any, might improve them. Careful and realistic planning by the teacher is needed to accomplish this type of activity.

Teachers also need to develop problem situations that gradually increase the demands made on students. This, too, requires careful and realistic planning. Equally important, teachers need to devote a regular portion of classroom time to teaching and using problem solving tactics. Rouse (1965), for example, used daily lessons of 30 minutes each and the Rosses prescribed instruction for four 15 minute lessons each week. The fact that both studies showed that retarded students gained significantly in a period of only 6 weeks should emphasize the importance of building problem solving activities into the normal routine of the class.

From this brief discussion, it should be clear that problem solving tactics that are useful for mildly handicapped learners are neither exotic nor special; they are everyday commonsense procedures. For the retarded student, however, it is necessary to teach the tactics directly and intensively. Further, the tactics must be applied to the types of problems that have meaning and importance to the students.

3 Discovery-Type Inductive Strategies

The review of research on problem solving strategies in the *Handbook of General Psychology* (Wolman, 1973) ranges from strategies that are peculiar to an individual to highly organized, logical systems that can be used by anyone who learns how to apply them.

INDIVIDUAL STRATEGIES

While individually devised strategies are provocative and interesting, they generally work best for the individual who conceives them. Some are so esoteric that they defy explanation. Others are so complex that they are costly in both time and effort. Sometimes they are so ingenious that only the originator can fathom the convoluted reasoning that results in problem solving.

There are, however, important drawbacks in relying on most mildly retarded learners' devising their own problem solving strategies. For one thing, the teacher is placed in the role of reactor since the student must show some evidence of a problem solving style before the teacher can begin to act. For another, the teacher needs to be able to discern the style and ascertain whether or not the student is using it in a systematic or random manner. Multiply the demands made on the teacher by the number of students in the class and you can see that this approach to teaching problem solving is both time consuming and inefficient.

Nonetheless, individually devised strategies may be valued for what they reveal about the student who uses them. They are signals to the teacher that, in some way, through modeling, trial and error, or directed instruction, the student has worked out a system to cope with problems.

Teachers need not wait for students to demonstrate a problem solving style before they act. Research shows that reasoning is an acquired skill. It follows, then, that teachers can take the initiative to develop students' problem solving skills in much the same way that they develop skills in the three R's. It is important for the teacher to establish a climate in the classroom that facilitates students' learning and practicing reasoning skills. To achieve this, the teacher needs to schedule problem solving activities on a regular and predictable basis, to establish mutual trust and respect in the classroom, and to capitalize on the interests and experiences of students.

The content for problem solving activities may be drawn from the many facts, concepts, rules, and principles that are the foundations for sound personal and interpersonal growth, as well as from academic content. By using content that has relevance for the students in their daily lives, opportunities are always available for them to practice reasoning skills once they have been learned. The importance of using activities that are relevant to the needs, interests, and learning characteristics of mildly handicapped learners cannot be underestimated. It is, perhaps, one of the strongest motivators for learning and for retaining what has been learned.

Previously, two systematic strategies for reasoning were discussed: inductive and deductive strategies. It was pointed out that an inductive strategy is most effective when we have (a) a problem and (b) an array of known facts that relate in some way to the solution of the problem, but (c) lack knowledge of the principle or rule that underlies the type of problem with which we are confronted. Deductive reasoning, by contrast, was described as problem solving that departs from a known principle or rule that helps us (a) to assemble the facts available, (b) to hypothesize, if necessary, about missing facts, and (c) to arrive at a solution. Following these actions, we are in a position to verify whether or not we chose the appropriate principle or rule to act upon.

The problem of traveling from one end of Manhattan to the other is an example of using an inductive strategy. We were able to eliminate walking and taxis because we knew that we were pressed for time and money. Putting together what we could induce about the similarities and differences in the types of public transport available to us, and the conditions of travel peculiar to each, we decided that the subway would be the better way to travel. Once we arrived at our destination we verified that our decision was the appropriate one. In this way, we solved our problem and learned a principle governing travel in cities where similar alternatives are available. Using a deductive strategy, we showed that the principle learned in our Manhattan travels was put to use when we faced a similar problem in San Francisco.

Deductive reasoning is, more often than not, a quicker and more facile strategy. However, it can be used effectively only if the problem solver has the necessary principles and rules stored in his or her

knowledge bank, an attribute usually associated with the acquisition of experience and maturity. Clearly, then, inductive strategies are more elementary; they are the first stage in developing students' abilities to solve problems in systematic ways. Inductive strategies provide students with learning experiences from which the rules and principles required for effective deductive reasoning may be acquired. This is not to say that deductive reasoning must be delayed until many rules and principles have been learned, but that it will probably take time and many experiences in the inductive mode before deductive reasoning becomes a student's primary problem solving strategy.

The remainder of this monograph will concentrate on inductive strategies from the viewpoint of classroom teaching and learning. Three inductive strategies will be described with focus on a specific inductive problem solving strategy that holds particular promise for use with mildly handicapped learners. Some pertinent research and its implications for teaching and learning transactions in the classroom will be discussed.

There are three general strategies of inductive teaching and learning: (a) Discovery, (b) Guided Discovery, and (c) a Logical Inductive strategy. While there are numerous variations of these strategies, the three remain distinct as systems for teaching and learning. Most notably, the strategies may be distinguished by the roles accorded to teacher and student. This chapter discusses discovery-type strategies and the next chapter concentrates on the Logical Inductive strategy.

Those who formulated and promoted discovery-type inductive strategies did so with nonhandicapped and often gifted children in mind. Moreover, the contexts from which these strategies emerged were, more often than not, mathematics and the sciences. These observations do not reflect negatively on discovery-type strategies; instead, they show that these strategies have been somewhat limited in their application.

DISCOVERY STRATEGY

The Discovery strategy is a philosophic and psychologic reaction to traditional teaching methods. Those who favor Discovery see it as a way to get teachers to stop lecturing at their students. It is viewed as a way to achieve a better balance between the roles of teachers and students by democratizing the instructional process in the classroom.

While there is widespread agreement on the value of the Discovery method and on the fact that it is inductive in nature, there is little agreement about precisely what it is and how it is to proceed methodologically in the classroom. Shulman and Keislar (1966) presented an array of papers that attempted to specify the elements underlying the method.

Many terms have been used in the attempt to define Discovery. Some authors have referred to this method variously as activity learning, free experimental techniques, or example-rule strategies. Morine

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and Morine (1973) elaborated the concept to describe the following types of Discovery: semideductive, structure, inductive, open inductive, and transductive. The main theme in the literature has emphasized a method of instruction where teacher-student interactions culminate in the student's evolving a solution to a problem rather than being told the answer by the teacher.

As Glaser (1966) characterized the process, it is a relatively unstructured instructional sequence and, therefore, relatively unguided by the teacher. The expectation is that the Discovery method will permit students to impose their own structure and order in dealing with a problem. This, however, allows students to pursue lines of thought that may lead to dead ends or misleading conclusions. To put it another way, using the Discovery method opens the door to trial and error learning and, as compared with more conventional methods managed by teachers, has more potential for error.

Some educators find appalling the notion of a teaching method that literally provides opportunities for learners to make mistakes. Nevertheless, it is a fact of life that trial and error learning is something we all experience in the ordinary course of events. While we strive to minimize the guesswork in our day to day problem solving, it would be safe to say that all our striving has yet to produce completely errorless days. The point is that making errors does not necessarily result in drastic or traumatic consequences. Most of us not only survive our errors but even learn from them what not to do in future similar situations. The issue, then, is not so much that Discovery allows opportunities for the student to make errors as it is the learner's ability to cope with mistakes—to take error in stride and to persist in exploration.

From the teacher's perspective there are two issues to be considered. First, there is the matter of time. With the many activities that need to be accomplished during the school day and through the school year, how much time can be devoted to random exploration? Can the teacher wait days, weeks, months for an important discovery to evolve? Is there a point when the teacher must call a halt to discovering in order to move on to other subject matter? Second, there is the matter of the teacher's own needs for a sense of accomplishment and closure. Is there a point when the effort expended in the quest for discovery transcends the value of the discovery itself? These questions have arisen often enough to raise doubts about the merits of the unstructured nature of the Discovery strategy.

GUIDED DISCOVERY STRATEGY

The Teacher's Role

Rather than surrender all of the potential instructional gains, an alternative was proposed in the form of Guided Discovery. Gagné and

Brown (1961) pointed out that Guided Discovery provides students the opportunity to speculate and search for relevant facts and concepts, as with Discovery. Unlike Discovery, however, the more outlandish hypotheses are eliminated through teacher guidance and the range of student exploration is somewhat reduced. Thus, Guided Discovery differs from Discovery in that the teacher enters into students' explorations when a cue will help them to avoid a conceptual cul-de-sac, or when calling their attention to a misunderstanding or misinterpretation of facts will alert students that they are moving in an unproductive direction. Weimer (1975) discussed a very different view of Guided Discovery. It was his contention that in Guided Discovery the teacher organizes and/or structures the learning event in some prescribed order to increase the probability that students will achieve a particular learning objective.

We might infer from Gagné and Brown and from Weimer that Guided Discovery is a compromise with the intent of the Discovery strategy, but this is not necessarily the case. The rationale for the Discovery method is to democratize the teaching-learning transaction by actively involving students in problem solving activities in the classroom. In the process, students' reasoning abilities would be stimulated. Students would benefit from experiences of involvement from which they gain a sense of accomplishment. Toward these ends, the Discovery method prescribes unstructured procedures that permit unlimited range to students' explorations.

While Guided Discovery is based on the same rationale, more structure is provided for students. Guided Discovery takes into account that there is an almost infinite amount of information available in any problem solving situation. It considers that in a particular problem solving situation certain information is relevant to the problem while other information may be irrelevant, confusing, or distracting. By using the Guided Discovery method, the teacher can act to reduce the irrelevant information that might be given undue attention by students. In this way, all participants in the process save time, effort, and psychological wear and tear.

To distinguish between Discovery and Guided Discovery methods, let us return to the problem of traveling from one end of Manhattan to the other. Using the Discovery method, the teacher might confront students with the statement, "We are invited to visit friends at their home at the north end of Manhattan. Here we are at the south end. How shall we get to our destination?" The problem, laid squarely on the students' plates, requires that they carve up the information that has been given them and assemble a palatable solution.

Using Guided Discovery, according to Gagné and Brown, the teacher would interact with the students on their terms until a student proposed an outlandish hypothesis. An example would be, "Why don't we go to the Wall Street Heliport and hire a helicopter?" In their view, the teacher might guide the discussion at this point by saying "Travel by helicopter is still very expensive. Besides, is it likely that

there will be a heliport near our destination?" Those who subscribe to Weimer's version of Guided Discovery would want to head off such a proposal in the first instance. They might do so by providing guidelines at the outset when the problem is introduced. For example, they might say, "Keep in mind that our hosts expect us to arrive at 6 p.m., and that we have an average of $4.00 to spend." In this case, the teacher has limited the scope of the students' thinking but has not limited their freedom to think. Some might disagree with the teacher's actions to restrict the scope of students' explorations on the grounds that the essence of Discovery is that it offers both the right to succeed and the right to make errors; that by structuring the problem, the teacher reduces a student's right to err. The view espoused in this monograph is that making mistakes is a part of learning and of life.

In the case of Guided Discovery, the issue is not so much that a student's right to make mistakes is reduced as it is that the range and nature of explorations may be abridged. Since proponents of Guided Discovery stop short of providing guidelines for structuring problem solving activities, it is the teacher who must exercise judgment about how and when to structure the process. Thus, control of problem solving activities is, implicitly, in the teacher's hands. Unfortunately, the state of the art is such that there is no way to know at what point structuring is helpful and when it is an intrusion on a student's creativity. Similarly, what may be an outlandish hypothesis to one teacher may contain the seeds of an important insight for another.

A crucial limitation in the effectiveness of both Discovery and Guided Discovery is the absence of a systematic management procedure for teachers. In the final analysis, it is the teacher's responsibility to designate most of the learning experiences of students as indicated by the objectives for individual students and the class as a whole, although relevant problem situations sometimes emerge that are distinct from stated instructional objectives. The teacher must capitalize on these according to his or her own judgment as they arise. Similarly, apart from achievement test data on students, it is the teacher who must evaluate the extent to which objectives have been achieved. Recent legislation requiring individual education plans for each handicapped student underscores the importance of stating and evaluating instructional objectives and, thus, of promoting teacher accountability.

It seems likely that the tendency to minimize teacher management in the Discovery and Guided Discovery methods is an outgrowth of attempts to generate and preserve a democratic atmosphere in the classroom, and of unlimited expectations for student growth emerging from their being given the freedom to think and to explore. In the first instance, attempts to evolve and maintain a democratic spirit in the classroom have been shown to be well worth the effort. The early studies of Lewin, Lippitt, and White (1939) demonstrated that teachers' democratic behavior, as contrasted with autocratic or laissez-faire behavior, promoted democratic attitudes in their students.

For all these reasons, Discovery and Guided Discovery strategies for teaching and learning have been popular until recently. However, with the rise of the competency testing movement and the corresponding pressure on the educational establishment to increase its emphasis on "basics," it is almost inevitable that classroom activities will become increasingly teacher directed. How this will affect mainstreamed mildly handicapped students will depend on the kinds of assistance available to the regular classroom teacher and to the student from special education personnel.

Establishing a balanced methodological role for teachers has many constructive features. These, however, are meaningless if we do not take the role of the student into account.

The Student's Role

Discovery, Guided Discovery, and all inductive strategies for that matter, assign important and active roles to students: those of explorers, synthesizers, decision makers, and evaluators. The ability and willingness of the students to participate are important factors in using these strategies. Inability or unwillingness to participate may vary from student to student. Some students may be unable to understand the problem as a whole, or some of its important elements. Others may feel that volunteering information leaves one open to criticism. Whether the reasons for nonparticipation are cognitive or affective, they merit attention since without the student's involvement in the problem solving transaction with the teacher, the lesson comes to a halt. Research conducted with nonhandicapped and gifted students showed that many were able to participate in these types of inductive learning experiences to one degree or another.

In contrast, experiences with retarded students suggest that most are unable to enter into Discovery or Guided Discovery explorations easily. The reader may detect an apparent contradiction with Tisdall's (1962) research in which he found that retarded students in experimental classes where an inductive method was used performed as well as nonhandicapped students on a test of productive thinking. Two facts, however, reduce the contradiction. First, the inductive method used in the study was neither Discovery nor Guided Discovery; it was a more systematically organized inductive method — the Logical Inductive strategy. Second, the students were of school entering age and were involved with the method from their first day in school. Thus, they did not have a history of negative learning experiences. They were willing to take risks.

To get a better understanding of the importance of the role that students' prior experiences play in enabling them to participate in inductive strategies, we turn to Suchman's (1961) experience. He attempted to train gifted fifth graders to develop inquiry skills that are important to participation in Discovery. Suchman was unsuccessful. He

described the failure producing characteristics of the students as follows:

> In a series of preliminary studies of about 50 fifth grade children whose intelligence was considerably higher than average we were able to determine some of the major difficulties that interfere with discovery through inquiry. To begin with, there was a marked lack of autonomy and productivity, stemming—we believe—from children's dependence upon authorities, teachers, parents and books, to shape their concepts. When given new data, or a situation in which such data were available, the children rarely organized what they had, rarely gathered more data, rarely raised and tested hypotheses or drew inferences. Instead they blocked completely, began to offer unsupported conclusions, or produced a string of stereotyped probes that led nowhere. Accustomed to having concepts explained to them in discussions, pictures, films, and textbooks, the children were unwilling or unable to plan and initiate action with the purpose of discovering new concepts for themselves—even when all the data necessary for such discovery were available on demand. (p. 155)

Nevertheless, it would be premature to conclude from Suchman's results that Discovery or Guided Discovery are necessarily unproductive methods. Reports by Taba (1961), Bruner (1961, 1966), and others are more optimistic. There is little evidence to support either a pro or con posture at this time.

SUMMARY

Shulman and Keislar (1966), in summarizing a conference on learning by Discovery, stated:

> Examination of both the exhaustive reviews of the literature and deliberations of the conference lead to an inescapable conclusion. The question as stated is not amenable to research solutions because the implied experimental treatment, the discovery method, is far too ambiguous and imprecise to be used meaningfully in an experimental investigation. (p. 191)

Strike (1975) suggested that ambiguities in the literature on inductive reasoning and Discovery derive from the confounding of two basic processes: formulation of hypotheses and the verification of hypotheses. Related to this is Wittrock's (1966) contention that failure to include verification as part of the Discovery method can lead to rather serious distortions of the method's intent. Specifically, he noted that teaching-learning transactions can begin to resemble a game of Twenty Questions rather than an orderly process of inquiry.

From the literature on Discovery and Guided Discovery, we may conclude for the present that while some authorities have been persuasive in their endorsement of these methods, there is little evidence that the methods provide effective strategies to improve students' reasoning abilities. However, this does not justify generalizing these reservations to all inductive strategies.

4 The Logical Inductive Strategy

While the rationales for Discovery and Guided Discovery have merit—the democratization of teaching-learning transactions, and the enhancement of students' reasoning abilities—it is questionable whether the use of these methods is appropriate with most mildly retarded learners. Their cognitive and affective characteristics require the type of teaching-learning transactions that will give them a better than even chance to succeed. Studies by Goldstein, Moss, and Jordan (1965), Ross and Ross (1973), Rouse (1965), and Tisdall (1962) indicate that a systematic and predictable problem solving approach is needed since such an approach is more nearly consistent with the abilities and experiences of retarded learners.

Systematic reasoning process models are not new to education or to psychology. Dewey's concept of the scientific method of problem solving evolved, in effect, into an orderly teaching-learning process designed to promote and enhance the reasoning abilities of students. He proposed five stages:

1. *Experience*, the first contact with new material.
2. *Problem*, evolving a problem that is real to students.
3. *Data*, information resources derived from the student's past and present experiences.
4. *Hypothesis*, a suggested solution to the problem based on data.
5. *Testing*, verifying the validity of the hypothesis.

Others (Guilford, 1967; Rossman, 1931; Wallas, 1945) have presented psychological models for inductive problem solving that indicate the steps an individual takes from first confrontation with a problem to its

solution. While all of these models focus on the individual, their structure and sequence permit them to be translated to a strategy for teaching and learning. This has been done in the form of the Logical Inductive strategy.

ATTRIBUTES

There are six attributes of the Logical Inductive strategy that differentiate it from discovery-type strategies.

1. The strategy offers teachers and students a structured procedure for teaching-learning transactions.
2. While the strategy is structured, it is not rigid. Teachers and students have a number of entry points into the system and alternatives if the selected entry point proves to be unproductive.
3. While the method is structured it is not undemocratic. The teacher's role is primarily that of stimulator and the student's role is that of responder. Teachers provoke response through their questioning. Students not only think through the problem and provide responses; they also act as evaluators of their own productivity.
4. The structure of the Logical Inductive strategy permits the teacher to assess quickly how far along in the reasoning process each student has progressed. This allows the teacher to plan interventions that will make it possible for a student to take the "next step" in the reasoning process.
5. The participation of the teacher at each step in the process allows quick recognition of students' errors or randomness in reasoning. This permits the teacher to intervene to reduce error repetition, digression, and frustration.
6. The structure of the Logical Inductive strategy does not restrict the student's ability to explore. The strategy makes it possible for the teacher to participate in his explorations, but teacher participation is not required. It is the teacher's judgment that determines when, how, and under what conditions involvement with the student's quest for information should take place.

The strategy is not based on the premise that there is a single correct path to the solution of a problem or the acquisition of a concept. Nor is it based on the assumption that there is a single predetermined solution.

The Logical Inductive strategy is appropriate for use in both formal and informal problem solving situations. Formal situations include those where traditional academic subject matter is the content of the lesson. Informal situations often arise during students' free time in or out of school. Typically, the difference between formal and informal situations is the teacher's entry point into the process. In most formal situations, the teacher is instrumental in confronting students with a problem. In informal situations, students often become sensitive to

problems that are part of their own life experiences. In both situations, the structure of the Logical Inductive method allows the teacher to judge the conditions for, and the point of entry into, interactions with the students.

THEORY

Gestalt theory provides a sound theoretical framework for inductive reasoning and, at the same time, an order for the process as well. Typical of learning theories, Gestalt theory is complex and worthy of in-depth study; this chapter will focus on those features of Gestalt theory that are relevant to the development of an inductive teaching-learning strategy.

Learning Stages

Gestalt theory says, in effect, that learning follows three stages: *Mass*, *Differentiation*, and *Integration*.

Mass

At the Mass or awareness stage, the learner is confronted for the first time with a "problem," and finds that it consists of an array of facts and concepts. Some are identified immediately as a function of prior learning and experience. Others might be new. At this point, it is not clear to the learner how all of the elements of the problem relate to each other.

Differentiation

To cope with the problem, the learner begins to sort out the elements of the Mass, and to examine how these elements are associated with each other. At this point, the Differentiation stage has been entered and the learner first takes inventory of the elements of the problem. He or she identifies facts and concepts and ties meaning to them by drawing on earlier experiences. The learner also makes inferences about the facts and concepts that are new. Having identified the elements, the learner discards those that are not relevant to the problem, then reassembles the elements according to their relationship to each other in much the same way that pieces of a jigsaw puzzle are fitted together. The processes of sorting, identifying, and reassembling the relevent elements of the problem lead the learner to a more precise understanding of the problem and, in turn, allow him or her to state possible solutions to the problem.

Integration

As understanding occurs and solutions are generated by the learner, he or she is on the threshold of the Integration stage. Once firmly

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aware of the meanings of the elements of the problem and how they fit together, the learner is well into the Integration stage. At this point the elements of the problem have become integrated into the individual's knowledge bank so thoroughly that similar problems can be solved quickly and with apparent ease.

Illustration of the Learning Stages

From this description of the learning stages in Gestalt theory it might appear that this is a simple process. To dispel this impression, we will illustrate the stages using the example of a teacher assigned to a new school at the start of a school year.

Many teachers, new and experienced, take positions in new schools each year. All are faced with the same array of problems insofar as settling in is concerned. There are personnel issues, which may include the climate of the school, the characteristics of the principal, the "closeness" of the teaching staff, among others. There are procedural issues such as the management of noninstructional duties, ordering and obtaining supplies and materials, and policies governing field trips. And there are problems with geography: learning to navigate the school.

As a function of their prior experiences as students, student teachers, and teachers, all teachers will have some general expectations as they come to grips with the multitude of problems they face. What they will need is time to learn the specifics of their new school setting so that they can adjust to them and eventually become an integrated part of the school.

Taking the most elementary of the new teacher's problems, let us look at how Gestalt theory operates to help the teacher solve the problem of learning the geography of the new school. We will join the teacher as he approaches the main entrance to the school and enters.

The Problem

"Where is my room and how is it located with respect to important places in the school? Where will I find the principal's office, teachers' lounge, library, supply room, toilets (theirs and ours), cafeteria, auditorium, etc.?"

Mass Stage

"Here I am inside the school. Corridors go off to my right, left, and straight ahead. There are doors leading to rooms, but I don't know which are classrooms and which are 'other purpose' rooms. On my immediate left is the school office, so the principal's office must be close by."

Differentiation Stage

"I'll ask the secretary for my room number and how to get there. Room

142—down the central corridor, second corridor, turn left. Here we go. Ah, there's the library, and just beyond it is a fire extinguisher. Here's the first corridor—no landmark—keep going. Here's the second corridor—turn left. First room is a custodian's closet. Next, there's a classroom. Across the corridor is a water fountain and the girls' toilet; the boys' is probably farther along. Room 142—here it is! There are double doors at the end of the corridor. Maybe that's the entrance to the cafeteria. I'll have to check that out.

"Now that I know where my room is, I'll use it as a focal point to locate the teachers' lounge and other places. For now, rehearsal time. If I want to get the the library, I turn right from my room, right at the central corridor, and watch for the fire extinguisher on the right. The library is the next room."

Clearly, the teacher is identifying relevant cues to the specific places he wants to find and is drawing on his past experiences to interpret a novel situation. Note that he did not include the color or texture of the floor or walls. Obviously, they provided no differentiating cues because the texture and color were constant in all parts of the building.

The teacher will use the same differentiating process to find his way to other places in the school. He will rehearse cues along the way, and may give himself verbal instructions to help him differentiate the route to the teachers' lounge from the route to the supply room. He'll make mistakes, too. When he takes a wrong turn, he will reexamine his cues to learn how and why he made an error. And he'll revise his cues accordingly. With practice, the places he visits most frequently will become the first ones for which cues seem to fade into the background. For example, the fire extinguisher may become so integrated into the gestalt of the hallway that he won't be able to remember whether or not the grafitti on the glass cover was cleaned off.

Integration Stage

At this stage, the new information has become an integral part of the new teacher's knowledge bank. Now he can travel from place to place without paying attention to direction or location cues. In fact, he can put himself on automatic pilot and think about professional, personal, or social matters while he travels around the building. In the process, he may still make errors but they will be fewer and less frequent. Occasionally, he might forget a landmark. Sometimes, new cues may be confused with cues that are relevant to other locations because of their similarity. But, again, practice will help to reduce errors and, in time, the teacher will navigate the school environment with ease.

In all probability, his integrated knowledge of the geography of the school will be combined with similarly acquired knowledge of the school's social structure and its customs and mores. For example, the

teacher will combine the fact that he can use the library as a shortcut to the teachers' lounge with the knowledge that the librarian frowns on this practice before 2 p.m. and he will avoid the shortcut prior to that time.

RELATIONSHIP BETWEEN GESTALT THEORY AND THE LOGICAL INDUCTIVE STRATEGY

With the mass, differentiation, and integration stages in mind, we can begin to explore the relationship between Gestalt theory and the Logical Inductive strategy. Clearly, the bulk of the problem solving activities occur during the differentiation stage. It is here that the actual sorting, associating, and reassembling of relevant facts and concepts takes place. It is at the differentiation stage that a reasoning process can either facilitate problem solving or, if it is unsystematic, make it more difficult. As noted earlier, discovery-type strategies do not provide a structure that allows an organized way to deal with facts and concepts. A Logical Inductive strategy structures the differentiation stage by providing a logical sequence to deal with the undifferentiated array of information found in the mass stage of a problem.

Reasoning Sequence

The reasoning sequence provided in the Logical Inductive strategy consists of five steps: labeling, detailing, inferring, predicting-verifying, and generalizing. The example used earlier, which dealt with travel in Manhattan, will illustrate the activity at each step.

Labeling

In this step, the elements of the problem are identified. When we started to solve the travel problem, we first identified where we were in relation to where we needed to be. Then we went on to name the ways we could get to our destination. We identified buses, subways, taxis, and walking as possible means of transportation.

Detailing

In this step, the identified (labeled) elements of the problem are described to better distinguish them from each other. Sometimes simple details are required, for example, the *tall* man. In our example, more complex and functional details are necessary. Buses travel scheduled fixed routes with periodic stops. They are surface vehicles affected by traffic conditions and controls. The cost of bus travel is low. Subways travel below ground. While they travel scheduled fixed routes, subways are only minimally affected by traffic and traffic controls. The cost is the same as riding a bus. Taxis are surface vehicles. They are not confined to scheduled or fixed routes, but are subject to

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traffic and traffic controls. Travel by taxi is far more costly than travel by bus or subway. Walking, a street surface action, costs nothing. It is much slower than vehicular travel, and requires greater effort by the individual.

Inferring

At this step, we are ready to propose possible solutions to our problem. As we review the data collected during the labeling and detailing steps, we can begin to structure information and choose feasible options. Given the information about buses, we can see that, on the asset side, the entire class can ride at minimal cost; on the liability side, travel time is not only lengthy but subject to unpredictable delays if traffic becomes heavy. Subways are noisy, often crowded, and not too scenic. However, they cover ground more rapidly than buses and at the same cost. Taxis, while surface vehicles, can change direction to avoid traffic jams. They are faster than buses and may be as rapid as subways, and they take travelers directly to their destination. However, they are limited in passenger capacity and are more expensive. Walking is cost-free and permits us to take expeditious routes. Since we need to travel a long distance, the trip will be exceedingly time consuming and will bring us to our destination well after the appointed time. Furthermore, such a great distance may be beyond the physical capability of some of our classmates. Our reasoning indicates that taxis and walking are not as good options as are the bus or subway. So our inferences regarding a solution have been reduced from four to two, the bus or subway. We are now faced with the need to select the better option.

Predicting-Verifying

This step involves making a commitment to one solution and then evaluating the effectiveness of the choice. In terms of classroom actions, we want the students to consistently weigh the consequences of their decisions. Thus, predicting and verifying are taught as linked behaviors with each prediction provoking questions about how the results can be evaluated. In the case of our travel problem, we recall from the detailing step that both the bus and subway travel scheduled fixed routes. To settle the issue, we call the Metropolitan Transit Authority to learn whether both forms of transport go to our destination and to get the scheduled times of departure and arrival for the bus and subway. Since both go where we need to go, we calculate the elapsed time and we are able to make a probability statement and predict that the subway is the better choice. In the course of the trip, we can verify the wisdom of our choice by comparing the scheduled and actual elapsed travel times.

Having reasoned the solution to our problem and having acted on it and verified the results of our decision, we are ready for the final step.

In this step, all of the information and experiences are combined in order to identify the rule or principle that underlies the solution to this general type of problem. Applying this step to our travel problem, we were able to use our experiences in Manhattan to facilitate solving a similar type of problem in San Francisco.

As we shall see from the research on the Logical Inductive strategy, generalizing is the most abstract and, therefore, the most difficult step in the process. More often than not, several problems within the same problem type will have to be experienced before a generalization emerges. For example, a group of mildly handicapped students might have to plan and take two or three trips to different destinations—where subway and bus are travel options—before the generalization emerges that subways are generally the quicker way to travel.

Procedurally, labeling and detailing are data collecting steps. The succeeding steps are data processing steps. Clearly, the effectiveness of the data processing steps is greatly affected by the language and perceptual abilities of the students. They must have the language available to name and describe the elements of the problem. They also need to understand how the elements and their descriptors relate to each other, and how they are relevant to the problem. With younger students, it is probable that teachers will have to concentrate on building a language response potential and a perception of how things relate to each other in different situations. All of this must occur before abstract reasoning, typical of inferring and predicting-verifying, can be attempted.

To help students make the transition from data collecting to data processing, the teacher needs to help them develop reviewing behaviors that they can use to constantly review labels and details as they begin to form inferences. In this way, the data collected early in problem solving become an information pool to be used in the more advanced reasoning steps.

It follows, then, that early and continuing language development and productive reasoning abilities are interdependent. Since this is the case, teachers need to have a reasonably accurate assessment of each student's vocabulary and comprehension in order to plan problem solving activities at appropriate levels. If students become mired in a problem that is too complex, progress becomes laborious, and confusion and frustration can result. This is not to say that every student needs to know every word or association before a problem solving situation is posed. If students have a reasonably adequate language base, they may be able to pick up the labels and details they lack along the problem solving route.

Since the final step in the Logical Inductive strategy, generalization, is pivotal to successful problem solving it is important to examine its role in the reasoning process. Inductive reasoning has two goals: immediate and long range. The immediate goal, solving the problem at

hand, is what has been discussed so far. The long range goal, evolving a rule or principle as an outcome of experiences with several related problems, is more difficult to attain. This is particularly true when the individual must evolve the rule or principle independently.

In the course of our schooling and life experiences, we have all been taught some rules directly. Sometimes we may not understand the why's and wherefore's of a rule (e.g., "i" before "e" except after "c"), but we are nevertheless able to apply it effectively. Few of us could attain our present levels of functioning, however, if we had to be taught directly every rule or principle that we act on. We have learned a sizable repertoire on our own. Some we can verbalize and some we cannot, but no matter. We can apply them as needed.

Similarly, mildly handicapped students can be taught rules and principles. However, no teacher or parent could ever begin to anticipate all of the rules and principles that a student might need a week, a year, or 10 years hence. Nor is it possible to teach all of the needed rules and principles in such a way that the student can (a) store all the needed information in his or her knowledge bank, and (b) draw upon it selectively, according to the demands of a particular problem. Like us, mildly handicapped students need to learn how to reason through immediate problems to increase the probability that they will, in time, discern and learn functional rules and principles that they can act on independently. This means that they will need continuous practice with real problems and with abstract thinking.

In an important sense, the generalization step represents the ultimate in abstractness. Compared to the preceding steps, all of which are rooted in the problem at hand, generalizations are more obscure. They can only emerge completely and assume functional properties if the student is able to comprehend associations among several similar problems and construct a relevant rule or principle. The ambiguity and complexity are highlighted if, upon reaching the generalization step, the student appears vague or confused. Questions which need to be asked by the teacher at this point include: Does the student understand the problem? Does he or she understand the problem, but not the rule or principle? Is the rule or principle emerging too early in the student's experience to be recognized? Is it so abstract that it is beyond the learner's cognitive capabilities? Or, is it possible that the student discerns the rule or principle but lacks the verbal skills to state it coherently? Obtaining answers to these questions requires that teachers constantly assess and reassess how they are structuring and asking questions. Patiently rewording questions and incorporating cues that help students organize their thinking can make the difference. Too, the teacher's careful selection of problems and consistent implementation of the reasoning process will go a long way toward reducing ambiguity. An especially important result of the research on the Logical Inductive strategy showed that students adopt the strategy as a problem solving tool in the course of learning how to use it.

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RESEARCH BASES FOR THE LOGICAL INDUCTIVE STRATEGY

The assumptions that problem solving is hierarchical and developmental form a foundation for the Logical Inductive strategy. When we say that the problem solving process is hierarchical we mean that it is systematic and that it progresses from simple to increasingly complex steps. Further, we make the assumption that information gained at each step is necessary in order to move to the next higher step in the problem solving process. We also propose that the problem solving process is developmental; that the process is related to the physical and mental growth of an individual. Thus, we assume that the maturity of an individual plays a part in his or her achievement of each step involved in problem solving.

Children's Analysis of Social Situations (CASS)

To test the assumptions that problem solving is both hierarchical and developmental, Greenberg and Smith (1974) used the Children's Analysis of Social Situations (CASS) devised by Lehrer, Greenberg, and Melnick (1972). The CASS was adapted from the Test of Social Inference (Edmonson, deJung, Leland, and Leach, 1970), a test designed to measure social competency and adjustment skills of retarded adults.

The CASS included 15 pictures of individuals and common objects arranged in a variety of social problem situations. Mildly retarded children, ages 6 to 12 years, were asked to respond to the same series of questions about each picture. The questions were designed to elicit the child's version of what was happening in the picture, a statement about what might have led to the situation, and a prediction of how the situation might be resolved. The children's responses demonstrated their abilities to *label, detail, infer, predict*, and, to a lesser extent, *generalize* information about each of the pictured social problem situations.

Greenberg and Smith's results confirmed the assumption that there is a hierarchy of steps in the Logical Inductive strategy for problem solving. They found that mildly retarded children needed to be able to attach correct labels to things and people before they could provide relevant details about what they had labeled. For example, a child needed to be able to identify an object as a ball before the relevant details "round, green, big," could be elicited. Similarly, before the children were able to make inferences about the problem situation, they needed the information gained at the earlier steps of labeling and detailing. The ability to predict was based on success at the lower steps in the Logical Inductive strategy and the ability to generalize relied on competence at all of the preceding steps.

This progression of interdependent actions is not unlike the axiom, "You have to crawl before you can walk, and walk before you can run." It seems that a similar principle applies: *Success at simple actions forms a foundation for attempting increasingly more complex*

actions. If this is so, the developmental nature of problem solving should also be supported.

To determine whether or not problem solving is developmental, the researchers examined how the children's ages related to their performance at each problem solving step. They found that 6 and 7 year olds were able to provide labels and details for the pictured situations but were unable to respond at the succeedingly more complex steps. In contrast, the 11 and 12 year olds were able to label, detail, infer, and predict about the pictured situations. However, only a small number of the oldest students in the study were able to make generalizations. Thus, support was found for the assumption that problem solving is a developmental process.

As they had analyzed the relationship between age and performance using the Logical Inductive strategy, Greenberg and Smith also examined the relationship between measured intelligence and problem solving performance. Numerous studies have reported a significant relationship between IQ and reading. Perhaps for lack of more complete information there has been a tendency to generalize this relationship across all types of school performance. The researchers found only a small relationship between measured intelligence and mildly retarded learners' performance using the Logical Inductive strategy. Thus, the fact that IQ and social problem solving are less well related than are chronological age and social problem solving suggests that sweeping generalizations about the IQ as a predictor of all types of school performance may be unwarranted.

In the course of testing, the researchers noted a change in the test behavior of the children. As they became more aware of the questioning sequence, the children began to anticipate questions and to give more complete answers. Their performance improved. The examiner's role diminished as the children's role expanded during the test situation. It appeared that some mildly retarded learners were able to detect the Logical Inductive strategy and to use it independently of the examiner's guidance. Thus, Greenberg and Smith considered the possibility that the testing situation provided a quasi training experience for the children. They incorporated this notion into their revision of the CASS.

Test of the Hierarchy of Inductive Knowledge (THINK).

Smith and Greenberg (1978) evaluated the information gained during the administration of the CASS and revised the test accordingly. While they continued to use pictured social problem situations and an interview procedure, they made several revisions in the substance of the test.

1. The content of the pictures was revised to present three pictures of similar problem situations from which a single rule or principle (generalization) could be generated. This allowed the children to

have three experiences with similar situations before they were asked to generalize an abstract rule that applied to the situations. This test revision was important because it allowed children to gain experience from repeated attempts to solve related types of problems before they generalized from their experiences.

2. A set of resolution pictures was provided showing the obvious solutions to each of the pictured social problem situations. This step allowed the children to verify the accuracy of their prediction about how to solve each situation, a step that had been lacking in the earlier test. This revision resulted in the incorporation of a "prediction-verification" step into the Logical Inductive strategy as the step preceding generalization.
3. The interview procedure was modified and expanded to provide better differentiation of the children's reasoning abilities. Specifically, efforts were made to distinguish between individuals who were having difficulty with the problem solving process and those who were having difficulty with the content of the pictured situations.

Each of the revisions further structured the test situation. Thus, when children responded to the structured interview, their performance provided an estimate of their manifest reasoning ability under the guidance of the examiner. This type of performance is similar to that expected of students in classroom settings where most of the problem solving is directed by the teacher.

The researchers were equally concerned with assessing the ability of retarded learners to use the Logical Inductive strategy independently. You may recall that while using the CASS, Greenberg and Smith found that some of the children seemed to apply the strategy with decreased guidance by the examiner. They devised situations similar to those in the structured portion of the test to allow the children opportunities to work through problems on their own. A child's demonstrated ability to cope with each step in the Logical Inductive strategy was interpreted as an index of self initiated independent reasoning ability.

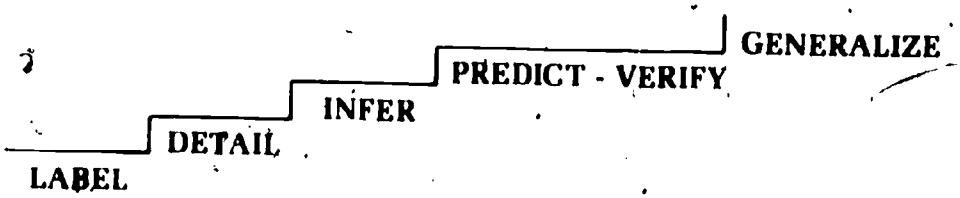
These changes and additions become a new test, the Test of the Hierarchy of INductive Knowledge (THINK), so named to draw attention to its major focus: the assessment of an ordered sequence of problem solving steps (Greenberg, 1977; Greenberg and Smith, 1978; Smith and Greenberg, 1978). The purpose of the research was to gain information about the following questions in a more rigorous manner than that found in earlier studies:

1. Are the steps in the Logical Inductive strategy hierarchical? Is competence at the first step a prerequisite for success at the next step, and does this pattern repeat itself at each succeeding step?
2. Are the steps in the Logical Inductive strategy developmental? Does the chronological age of mildly retarded learners have a bearing on

their performance at each step in the strategy? Do older children tend to perform better at each step? Are older children more able to solve problems independently than younger children?

Mildly retarded learners between the ages of 9 and 14 years were the subjects in this study.

The results of the research using the THINK closely parallel those found in the earlier study with the CASS. Again, the steps in the Logical Inductive strategy were found to be hierarchical. The data showed that the strategy represents an increasingly complex set of reasoning operations. It was also found that success at each step was a prerequisite for attempting to reason at the next higher step. This information is important since an additional action was incorporated and tested, prediction-verification. The steps comprising the Logical Inductive strategy are as follows:



To learn whether or not students' performance using the Logical Inductive strategy was developmental, the researchers assessed the relationship between age and performance. Their results generally justified a conclusion that there is a developmental pattern to mildly retarded learners' performance using the strategy.

All of the children were successful at the labeling and detailing steps, a result that was consistent with earlier work using the CASS. (It should be remembered that the youngest children in the THINK study were 3 years older than those who participated in the CASS research.) In succeeding steps, however, age began to play an important role.

About halfway through the test, children were asked to give a statement of the problem. The responses of the 9 and 10 year olds were not only less productive but they required greater effort than the responses made by children who were 11 years or older. The older children were also better able to associate the relevant parts of each problem, and their responses were more spontaneous. All of the children were able to make some inferences about possible ways to solve the problem and to offer a judgment about the appropriateness of the solution for the problem. The 9 and 10 year olds often gave only one or two inferences and produced fewer correct inferences. The 11 and 12 year olds tended to give a greater number of inferences. More often than not, they gave both correct and incorrect inferences and showed an awareness of the correctness of one solution and the flaws in the others. Children in the oldest group, ages 13 and 14, gave fewer

inferences but most frequently stated the correct inference. It was clear that their ability to make correct inferences inhibited their stating incorrect inferences: these children were more sure of themselves.

At the prediction step, all of the children were able to state one "best" solution to the problem. At the predicting-verifying step, they were able to use the problem resolution pictures to confirm or reject their solution.

Chronological age also was a significant factor at the most abstract level of the Logical Inductive strategy, the generalization step. Fewer younger children were able to comprehend the task they were asked to perform at this step. By contrast, although the older children understood what was required of them, few were able to state an appropriate generalization from the sets of pictured social problem situations.

To summarize, Smith and Greenberg found that the younger students were able to label and detail the parts of a problem situation. However, they had difficulty separating relevant labels and details from those that were irrelevant. This seemed to limit their ability to make inferences about solving the problem. Children in the middle age group were able to label, detail and make inferences. Their inferences, however, showed a limited set of choices for solving the problem, and they had difficulty verifying predictions about the merit of the solution they had selected. The oldest children in the study were able to use all of the steps up to the generalization step effectively. The abstract nature of generalizing, requiring the student to integrate experiences with three similar but different problems into a rule or principle underlying their solution, was too difficult for the 13 and 14 year olds. It appeared that practice in developing this skill had not been a part of the children's educational experiences.

On the portion of the test where the children were given opportunities to use the Logical Inductive strategy independently of the examiner, it was not unexpected to find that they performed less well than they had done under the guidance of the examiner. Similarly, it was not unexpected that the children who had demonstrated an ability to anticipate questions in the structured interview and who were able to make some attempt at forming generalizations were more competent in the independent problem-solving tasks. Interestingly, most of the children's responses were more sophisticated on this portion of the test than they had been under the guidance of the examiner. This suggests that there was some carryover from the structured testing situation to the independent problem solving situation.

All of the children were able to label and detail the elements of the situations that were presented. In some cases, however, entire categories of responses were omitted. For example, in the structured interviews questions were asked about the emotions shown by the people in the pictures. When functioning independently, it seemed that the children ignored these more subtle cues to the social situations that were depicted in the pictures. At the inferring, predicting, and

generalizing steps the children's responses were more variable and unsystematic than they had been during the structured portion of the test. The children produced fewer solutions to the problems, and the solutions tended to be more concrete. There was also less self direction at the predicting-verifying step. Most of the children tried to construct a continuous story from the resolution cards rather than to select the best probable solution. The children who had learned how to use the problem resolution pictures during the structured part of the test were clearly discernible by the way they sorted the pictures to make their selection, and by the way they described how the problem could be resolved. These children were also the only ones who were able to generalize a rule governing the solution of the problem.

Comparing the performance of the children on the two parts of the TTINK allowed the researchers to speculate that the independent problem solving ability of mentally retarded learners may be less well developed than is their ability to perform under the direction of another person. Such is the case in view of the findings that the children produced fewer responses and more limited responses when they were working independently of the examiner's guidance.

As they had done in their earlier study of problem solving, Greenberg and Smith (1978) again related measured intelligence to the manifest reasoning abilities of mildly retarded learners. Again they found that IQ scores were less valuable as predictors of problem solving ability than was chronological age. The practical implication of this important finding will be discussed in detail in the next chapter. Let it suffice, for the moment, to recognize that this is a most encouraging piece of information since it allows us to expect that retarded learners' problem solving abilities *can* improve as they get older. This is quite a departure from the notion that IQ, as a single measure, establishes the potential that an individual can reach.

Summary of the Research on the Logical Inductive Strategy

From the two studies reported on the Logical Inductive strategy, we have learned that:

1. Problem solving is a hierarchical process. The steps in the process are interdependent, in that success at the lowest step is a prerequisite for attempting action at the next higher step.
2. Problem solving abilities are developmental; they are related to the chronological age of the child. This finding suggests that both readiness and prior experience are factors that have to be considered as we attempt to enhance retarded learners' abilities to solve problems.
3. Problem solving abilities are not as closely related to measured intelligence as they are to chronological age.

SUMMARY

To this point, reasoning has been described as a learned activity and research has been cited to show that mildly handicapped students, like others, can enhance their reasoning abilities by learning and applying a problem solving strategy. It was noted that the concept of an inductive approach to teaching and learning is well rooted in history and that a resurgence in advocacy of the use of inductive strategies occurred following Sputnik in the late 1950's. Two once-popular strategies, Discovery and Guided Discovery, were discussed whose stress on democratizing teaching-learning interactions in the classroom and enhancing the development of reasoning abilities of students has influenced current educational practices. It was found that interest in these inductive strategies has ebbed since evidence of their effectiveness has not generally met the expectations that educators held for them. Further, it was suggested that these strategies would not be effective to teach mildly handicapped students because they lack predictable sequence and structure.

The research cited, concerned with problem solving tactics, showed that mildly handicapped students could learn problem solving tactics if these were taught in a consistent and systematic way. Too, it was found that handicapped learners were almost as productive in creative learning tasks as their nonhandicapped counterparts when they were taught using a structured inductive strategy.

Subsequently, the Logical Inductive strategy was described in detail with particular attention to its three stages—mass, differentiation, and integration; and to the five steps that comprise the strategy—labeling, detailing, inferring, predicting-verifying, and generalizing. The research reported demonstrated that the sequence of the Logical Inductive strategy is hierarchical and that students' performance on problem solving tasks is developmental. The research also showed that chronological age is a better predictor of problem solving performance of mildly retarded learners than is measured intelligence.

5 Implementing the Logical Inductive Strategy

Teaching strategies and tactics, like almost all educational activities, gain meaning only when they are put to use. For teachers, a discussion of the theoretical aspects of teaching strategies and tactics provides a foundation for implementation. Such a discussion is necessary, but not sufficient, to meet a teacher's needs. Attention must also be given to certain teacher characteristics and to the educational settings in which the strategy will be used.

From the earlier discussion of strategies, it is clear that they are not equal in terms of the amount of time and effort they require of the teacher. Experience tells us that rote teaching, as a style, is easier and less time consuming than inductive teaching. So, for the teacher who chooses to teach inductively there must be the additional commitment to structuring, sequencing, and assessing student performance using the strategy. There must also be a willingness on the teacher's part to relinquish sole leadership of all classroom activities to give the students a greater participatory role.

We must also take into account the "back to basics" movement that is currently prevalent in the educational community. One need only look at the emerging competency testing movement for confirmation of the pressure on boards of education and school administrators to increase the academic performance of students. In special education, we are faced with a similar demand: the need to raise the academic performance of mildly handicapped students so that they can be mainstreamed.

If teachers need to improve academic achievement scores in order to satisfy the pressures placed on them, the temptation to "lecture" about both facts and concepts is great. Although research suggests that rules

and principles are better learned in a problem solving (inductive) context (Klausmeier & Hooper, 1974). Staats (1968) speculates that rote learning may evolve into concepts as a function of students' social experiences.

Since the issues are not clear cut, there might be some justification for teachers to subscribe to a teaching strategy that allows them to cover a lot of academic content quickly. However, the justification only becomes credible to the extent that we are willing to accept that the major, if not exclusive, objective of educating mildly handicapped learners is to expand their academic skills and proficiencies. Few would agree that this is the case. The objectives of education for handicapped children must also include their psychological and social development. Taking the full range of educational objectives for handicapped learners into account requires that we (a) resist making expedient decisions about teaching strategies, and (b) adopt a repertoire of teaching strategies that reflects the role of the schools in students' maturation.

STUDENT SELF CONCEPT

How do these issues apply to the education of mildly handicapped students? Foremost, we need to keep their learning and psychological characteristics in mind. For example, it is generally agreed that a substantial number of handicapped students hold somewhat negative views of their competencies (Cromwell, 1968) and that their lowered self concepts interfere with learning. A popular and well accepted remedy for this problem is found in structuring opportunities for success. Teachers typically select tasks that are reasonably within the accomplishment range of students and then are careful to reward successful accomplishments adequately. In cases like this, students are being faced squarely with evidence of their competencies and of their ability to succeed.

This type of overt approach to help students build positive self concepts is worthy of endorsement. However, the strategies used in the course of day to day instruction give students subtle clues about their teachers' expectations for their performance that likewise affect self concept.

What type of message does a teacher convey when his primary approach to teaching is by way of a rote strategy? A look at the procedure can be very revealing. The teacher:

1. Tells the students what is to be learned.
2. Prescribes the students' actions, e.g., repeat after me, write it five times, etc.
3. Calls on students to respond.
4. Tells the students if they are correct or incorrect.
5. Corrects the students by prescribing another activity.

The message comes across loud and clear: look to the teacher for what is to be learned, how it is to be learned, and to find out whether or not you have learned what you were taught. As a daily experience, this view of one's role in school hardly fosters feelings of confidence, competence, and independence apart from the reinforcement received for following orders.

Now let us look at the messages conveyed by the teacher who uses inductive or, for that matter, deductive teaching strategies. These strategies, characteristically, are almost devoid of "teacher telling" actions. While teachers most often designate the learning objective and may even construct the problem that is the source of the learning objective, it is the students who identify and state the problem as an outcome of the teacher's questions. Too, it is the students, guided by the teacher's questions, who solve the problem and verify the appropriateness of the solution before they move on to evolve the rule or principle that governs the solution of similar problems.

Unlike rote strategies where teachers tell and students do what they are told, inductive strategies allow the teacher to ask and permit students to participate as they choose. If they are, for some reason, unready to participate they are still involved as they observe their classmates' participation. In time they may realize that participation is doubly rewarded. First, students are rewarded for simply responding. Second, if their response is partially or wholly correct, they are rewarded with a "well done." Even if a response is incorrect, there is no retribution. Instead, the teacher backtracks with them to assist as they reorganize the information about the problem and/or to restate the problem, whereupon they are rewarded for taking part in the restructuring activities.

Students and teachers are equals as they engage in inductive problem solving. The teacher's message, inherent in the strategy, is "No matter how you see yourself, I see you as an able person who can succeed. Otherwise, I wouldn't ask you to join with me in this activity." Daily experiences of receiving this kind of message can go far to shore up flagging self concepts. While evidence that inductive teaching can be constructive in developing students' positive self concept is not overwhelming, this may be because so little research has been done on the subject. The evidence that is available is worth noting, however.

For example, the study of the efficacy of special class placement (Goldstein, Moss, & Jordan, 1965) showed that students in classrooms where the inductive strategy was the dominant teaching style were greater risk takers than students in classrooms where the teaching styles were more eclectic. To illustrate, these students were asked to answer a list of questions that started with questions that all could answer, progressed to questions so difficult that they could not possibly answer them correctly, and then back to questions which they were capable of answering. The special class students in the experimental group not only answered the easy preliminary questions but

also attempted to answer the very difficult questions. When they were again confronted with questions within their capability, they continued to respond and answered correctly. In contrast, the comparison group of students answered the first group of questions with ease but became more and more defensive as they were confronted with the difficult questions. They responded with "I don't know" to all of the difficult questions but, more importantly, they continued to respond with "I don't know" to the easier questions at the end of the test. Their confidence had been so badly shaken that they were afraid to take risks.

The results of the study confirmed predictions made by the researchers using Rotter's (1954) expectancy theory. According to the theory, expectancies influence the behavior of students. Students who had had classroom experiences that promoted expectancies of success would be more inclined to answer both the easy and difficult questions. By contrast, students who had classroom experiences that promoted expectancies of failure would find it difficult to cope with responding to the "answerable" questions following their failure to answer the difficult questions that preceded them.

To avoid giving the impression that the inductive strategy only showed positive results with content in psychosocial areas, it should be added that the children in the experimental group also performed successfully in academic areas. After the first 2 years of the study, they were on a par with their regular class peers in arithmetic computation and were significantly superior to them in arithmetic problem solving. The special class teachers felt that their students' enhanced reasoning ability made the difference in their quantitative thinking ability. The teachers were also of the opinion that their emphasis on skill development in reading, with much less concentration on comprehension, accounted for the less remarkable differences in this aspect of their students' academic achievement.

Experiences with the efficacy study showed how expectancies for success, apparently generated by students' experiences in an inductively oriented classroom, can become generalized. Observers noted that, over time, students who had been reluctant to get involved in the teaching-learning transactions began to participate as they found that the "failures" at home and elsewhere were not materializing in the classroom. "Silent" students became voluble, contributing members of the class. A related result, from Smith and Greenberg's research, showed that a significant proportion of the students whom they tested adopted the Logical Inductive steps to solve the problems presented to them by the examiners.

It would appear, then, that students who participate in systematic and logical approaches to problem solving not only adapt to the system but also adopt it for their own problem solving purposes, and ultimately use it independently. How quickly and successfully this oc-

curs depends on a number of factors, not the least of which are the student's prior experiences. For example, all of the students in the efficacy study, experimental and comparison, were of school entering age when they were randomly assigned to classrooms. Thus, none of them brought into the study either positive or negative school experiences. Teachers in the experimental classes did not have to cope with the usual negative attitudes toward school learning experiences as they began to implement the Logical Inductive strategy with the students.

Putting this information together, it is possible to see how enhancing the willingness of the students to take risks might enhance their positive self concept as well. Perhaps the self concept strengthening experiences of the children in the experimental group made it possible for them to try to answer all of the questions posed to them; the possibility of being wrong did not loom large as a negative consequence. This did not seem to be the case for special education students who were placed in regular classes. It seemed that these children experienced the types of failure in their classrooms that is so much a part of the educational literature (e.g., *Why Johnny Can't Read, Children Who Fail*) and that these experiences influenced their behavior on the test. Specifically, these children were unable to recover enough of their "self" to tackle the answerable questions following their failure with the difficult midtest questions.

Some readers might question the experimental students' willingness to persist in attempts to answer obviously impossible questions. Might this not suggest an unrealistic self concept that could lead to self destructive experiences? Is the development of an inductive approach to problem solving justified? In responding to these questions, it is helpful to recall that the problem solving step, *predicting*, is linked with an evaluating step, *verifying*. Thus, students become accustomed to acting and then immediately checking the results of their action. The questionnaire with which they were confronted was not presented inductively. The students were told by the examiner (not their teacher) that he was going to ask them a number of questions. He encouraged them to do the best they could. The students received neither positive nor negative feedback on their answers. Thus, the responses of the experimental students did not suggest flightiness or foolhardiness in attempting to cope with the questions. Instead, they were willing to try and to risk making errors.

The behavior shown by these students is consistent with our view of productive problem solving, in that we would prefer to see mildly handicapped students adopt a reasonably assertive approach. A problem unassailed is, inevitably, a problem unsolved. By attempting to cope with a problem, the probability of solving it is increased. A key objective of the Logical Inductive strategy is to develop in mildly handicapped persons a constructive approach to problem solving, along with positive personal attitudes.

FOLLOWUP STUDIES

While it is important for mildly handicapped students to be competent in school, this importance pales alongside the significance of having them develop competencies that provide the foundation for their adjustment to the mature world beyond the school. It is important to recognize that the education provided these students during their school years has its real payoff once they reach school leaving age.

Compared to the school years, an individual's adulthood is far less structured, goals are less well defined, support and resources are less accessible, and the consequences of actions are far more dramatic. The nature of the adult world requires a great deal of independence in every aspect of living. The teacher is no longer present to guide, to motivate, or to confirm the appropriateness or inappropriateness of solutions to real life problems. The individual who has not acquired problem solving skills and a self concept that allows him or her to cope with everyday problems faces a relatively limited lifestyle.

A reasonably good picture of the adaptability of mildly handicapped adults can be constructed from the reviews of research reported in the literature (Goldstein, 1964; Tizard, 1974; Windle, 1962). While the many followup studies cited varied in their designs and on the basis of changing economic conditions, nonetheless they showed that mildly handicapped persons had proportionately more difficulty in getting and holding jobs, in their marital relationships, and in their confrontations with the law than did nonhandicapped persons. Further, as a foundation for the development of the Social Learning Curriculum a survey was made of agencies serving mildly handicapped adults who were having job related problems. It was found that, in the majority of cases, the problems arose as a result of inadequate social skills. Foremost among these were reports of overdependence on others (Goldstein, 1969). The problems that removed many mildly handicapped adults from the job market could be traced to the inappropriateness and/or absence of decision making abilities in their personal, occupational, and leisure time lives.

It is important, then, that as we teach reasoning skills to mildly handicapped students as part of their curriculum, we also prepare them to use these skills in the future. In this sense, the strategies and tactics that teachers use should be presented so that students adopt them as problem solving tools in school and, at the same time, integrate them as aids to social adaptation that they can take into the adult world. Smith and Greenberg's (1978) research showed that an inductive teaching strategy that is logical and systematic can be learned by mildly handicapped students and used independently of teachers or other adults. Thus, when we consider the question, "Is it worth the time and effort required to teach inductively?" we find that the followup studies and research suggest that it is—particularly when teachers want students to acquire rules and principles for independent problem solving.

What is called for is as precise a designation of teaching strategies as possible: a rote strategy when retention and response are the necessary problem solving behaviors, and systematic inductive strategies when the necessary problem solving behaviors are evolving rules and principles that are to be learned as a basis for generalization. Mainstreaming makes it essential for mildly handicapped students to adapt to general education settings and to function as best they can in those settings. Mainstreaming is, in this sense, a prelude to confrontations with the adult world for mildly handicapped students. To prepare them to meet this challenge, the students must start early in their school careers to build the reasoning abilities they will need as adults, and teachers must provide them the opportunities to do so.

GETTING READY TO USE THE STRATEGY

Most, if not all, of the foregoing discussion is intended to make a case for logical inductive teaching as a process that is advantageous to the growth and development of mildly handicapped students. In the process, it may have seemed that to teach inductively is laborious and humorless, with little accruing to the teacher beyond what can be observed in the students' behavior. This is far from the case. Inductive teaching can be stimulating and pleasurable for teachers and students alike, once they begin to feel comfortable with the strategy.

There are certain prerequisites for becoming comfortable with the strategy. The teacher, for example, must be willing to take the risk of appearing less than all knowing to the students. He or she has to be sincere in saying to students, "We're faced with a problem and I need your help to solve it." Further, the teacher has to be able to delay gratification. Sometimes the desired responses from students are not as quick to emerge as they are when a rote strategy is used. The temptation to "give" information to students to get them over a rough spot may be strong. However, when the desired response is not forthcoming, the teacher should assess his or her own performance. Did the teacher ask the right question? Was it asked in a way that confused the students? Thus, for the teacher, the prerequisites to using inductive methods include having confidence in his or her ability to manage the process, being willing to take the time needed to have students participate in the process, and believing that the students can successfully participate in problem solving activities.

Students, too, have adjustments to make. Some may be dumbfounded when the teacher initially tries to involve them in problem solving activities since, for them, it may be a first time experience. With encouragement, many of these students can become eager collaborators. In fact, one informal measure of self concept is the amount of time it takes a student to accept that the teacher's confidence in his or her ability is based on fact.

Teachers and students have to face the reality that students will not acquire uniform reasoning abilities; as with all human attributes, stu-

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dents will demonstrate a range of reasoning abilities. Some students will be quick to learn the strategy. Others will be weaker in certain aspects of the strategy than in others and will need assistance to sharpen their skills. Still others will find the whole process difficult, and some may not progress much beyond the data gathering steps of labeling and detailing.

When students have particular difficulty with an aspect of the strategy the temptation to relieve struggling and frustration by providing answers may be strong. Before giving up, however, teachers should satisfy themselves that they are not being hasty. When it appears that an impasse has been reached, it is the teacher's judgment that prevails. The fact is, though, that the information gained about themselves and their students' reasoning abilities during the early stages of implementing the strategy can help teachers make accurate judgments at this juncture.

GUIDELINES

It is not possible to anticipate all of the problems that might surface in the course of teaching inductively. Our observations and experiences, however, provide some guidelines that can be used to assist at each step in implementing the Logical Inductive strategy. These are: (a) planning and (b) selecting teaching objectives.

Planning

Planning for inductive teaching is based on the following goals:

1. We want students to increase their fund of knowledge.
2. We want students to learn how to solve problems (reason) in a systematic and productive manner.
3. We want students to learn the rules or principles that underlie the solutions to classes of common problems, e.g., managing personal affairs, getting along with others, etc.
4. We want students to acquire the self confidence that will allow them to cope with their problems independently.

To meet these goals, planning for students' experiences should be purposeful and comprehensive. Experiences should build one upon another, starting at a level that is consistent with the student's state of knowledge and proceeding to higher levels of problem solving at a rate consistent with his or her abilities.

A quick estimate of the relevance of prospective experiences can be made by asking: Is the problem a high priority learning need for my students? Can they identify with the problem? Do they possess the basic knowledge, e.g., facts and language, needed to tackle the problem?

Selecting Teaching Objectives

Once planning for inductive teaching is underway, selecting teaching objectives follows. We need to decide how the prospective activity fits the maturational needs of the students. We need to ask whether a particular objective provides experiences that are relevant to both the immediate and the long range needs of the students. Without question, the students need to be able to adapt to their immediate world. At the same time, however, they need to begin to acquire skills that will materialize as competencies a week, a year, or 10 years from now.

There is a temptation to focus exclusively on immediate problems. For example, the students may not be working well together. Class projects suffer. Those with limited skills are being demeaned. Problem solving experiences are indicated that address these problems. However, we also know that these students will someday leave the schools and may face similar experiences in the community. Shall we address one or both of these issues as we select our teaching objective? This is a familiar and frequent type of decision for most teachers. There are no easy answers. To avoid oversimplification, we suggest that teachers carefully consider both the immediate and long range implications of the teaching objectives that are selected.

USING THE STRATEGY

With planning and the selection of objectives completed, the teacher is ready to involve students in activities that will lead to fulfillment of the goals. Each objective, then, represents an array of content that spans all five of the steps in the Logical Inductive strategy. To illustrate how an objective takes shape within a systematic inductive strategy the following lessons are provided.

The Problem

The teacher has found that most of the students in the class are very linear in certain aspects of their problem solving. They approach problems in concrete ways and seem able to use only conventional and available "tools" to solve the problem. When these tools are unavailable, problem solving either grinds to a halt or takes unexpected and undesirable directions. For example, when Eddie could not locate the scissors he stopped his work on the class mural. Faced with the same problem, Marcia substituted a nut knife for the scissors. She not only succeeded in cutting out the necessary paper for the mural but left a lasting impression in the surface of the work table because she cut directly on the surface as she had done with the scissors.

The teacher decided that understanding the concept of substitution was both an immediate and long-range need of the students; immediate because of Marcia's experience, and long range because everyone is confronted with situations where we lack conventional tools and

must choose an alternative way to accomplish our goal. Most of us have learned to substitute either directly, indirectly, or by trial and error. The teacher selected as the lesson objective to have the students learn the concept of substitution, with the eventual goal of evolving a rule or principle (generalization) to assist them in making decisions when they need to substitute.

How do we go from theory to practice? How does a teacher begin to use the problem solving steps to enhance students' knowledge and, at the same time, their ability to solve problems independently? At this point, there are two options. One is to contrive a real problem — needing to hang a picture when the most appropriate tool, a hammer, is unavailable. Another option is to display the problem situation graphically and to work out the situation verbally with the students. Experience has shown that the latter option is more serviceable early in the students' problem solving activities, particularly when the teacher is unsure that they possess the needed language and/or experience to participate. Confrontation with real problem situations is more often appropriate later in the sequence of lessons when real experiences can be used to reinforce the rule or principle that has been evolved by the students.

To illustrate how the teacher and students interact systematically, we will use stimulus pictures that were used as part of the Test of the Hierarchy of Inductive Knowledge (THINK). Viewing the stimulus picture, Figure 1, the teacher can see that the labels are: boy, man,

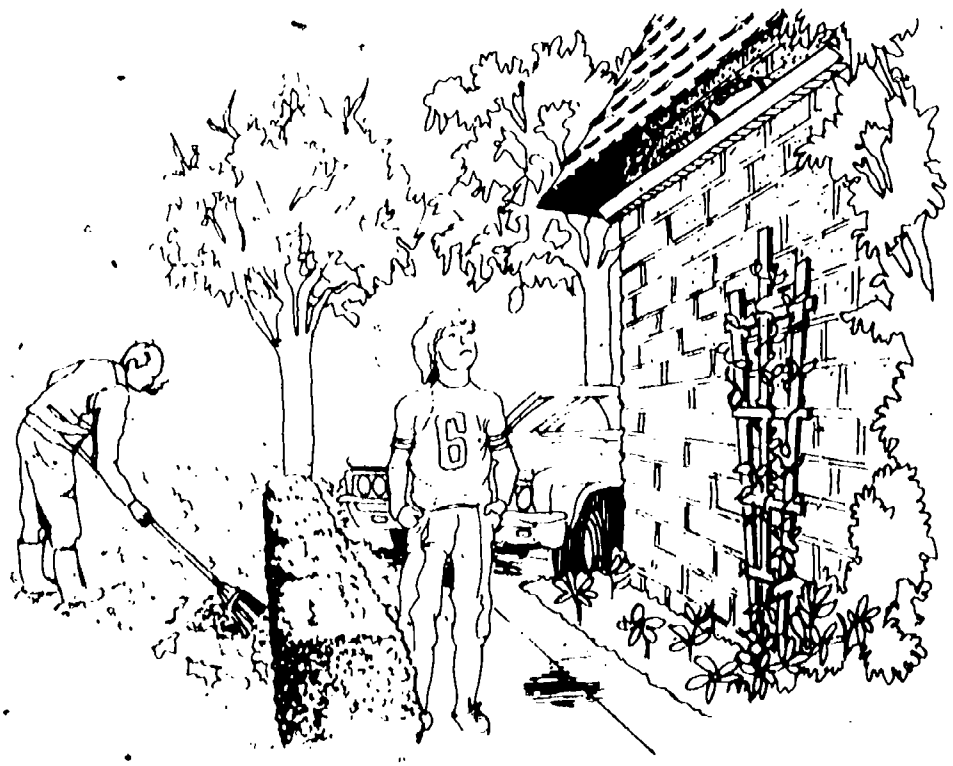


FIGURE 1. Stimulus Picture.

rake, trellis, flowers, car, driveway, football, numeral 6, eave, walk, leaves, hedge. Details in the picture include: man raking leaves, boy in football uniform, car in driveway, football in eave, flowers next to the garage, vines on trellis, and so on.

The teacher is aware that some students may not know the labels for trellis and eave. He checks and finds that he is correct. He teaches these labels to the students using a rote strategy.

He is also aware that certain objects do not contribute to the solution of the problem while others do. Since all labels and details have equal potential for being stated, the teacher will reward each statement, but will give additional reinforcement to responses that relate directly to the problem. He will make these distinctions because he knows that having a student verbalize a response calls for reinforcement, as does the correctness of the response. Both types of reinforcement are important if young students are to become participants in problem solving activities.

Simulated Lessons

The stimulus pictures will be used to simulate two lessons, one with a primary level class and one with an intermediate level class. In both cases, the lesson is part of a sequence of teacher managed activities designed to involve students in a situation where needed tools or aids are not available at the time that a problem needs to be solved. Keep in mind that the immediate objective is to have students substitute appropriately for conventional tools that they lack. The long range objective is to have them evolve a rule that governs effective substitution.

Primary Class

The primary class is made up of children ranging in age from 7 to 10 years. Consistent with the results of the THINK research, these students can label and detail, although they vary in their abilities to do so. They have less faculty for making inferences, predictions, and verifications, and are some distance away from making generalizations. The teacher wants to enhance their data gathering abilities and, at the same time, to move them toward making inferences.

Intermediate Class

The intermediate class is made up of children who are between the ages of 10 and 13 years. While the objective of the lesson remains the same, to have students acquire the concept of substitution, the teacher will initiate the strategy at a different point because she assumes that the students have the language necessary to cope with the problem.

The simulated lessons that follow are in the form of tapescripts.

Teacher: (Shows class Figure 1) Let's all take a good look at this picture. Now let's see if we can name all of the things in the picture. Who wants to start? O.K., Eddie, you can go first.

Eddie: I see a boy, car, football, garage, some flowers.

Teacher: Good, Ed. Who else wants to try? Yes, Marcia, go ahead.

Marcia: I see a man raking leaves, some bushes, flowers. (The teacher notes that Marcia is, in some cases, combining labels and details, which represents a more mature response than labeling alone.)

Teacher: Very good, Marcia. Now, let's all look at the picture again and see if Eddie and Marcia named all of the things in the picture. Bill, I see your hand.

Bill: The man has no hair on his head and he's smoking a pipe.

Teacher: Can everyone see the things that Billy named? Is he correct? Good, you're very observant. (Teacher singles out student who characteristically gives limited responses.) Louis, can you name some of the things that Eddie, Marcia and Bill have named? (Teacher encourages student to repeat as many labels as possible and does the same with one or two other students.)

(The teacher has reached the detailing step. At this point, he has two options. He can (a) encourage the students to give details about all of the things named if he is concentrating on enhancing their labeling and detailing skills, or (b) draw from students only those details about elements of the picture that have a bearing on solving the problem. In this case, the teacher wants to move ahead to the inferring step and will, therefore, focus on the elements of the picture that will help to solve the problem.)

Teacher: We said we saw a boy. Who can tell me something about the boy?

Eddie The boy is wearing a football sweater.

Teacher: Why do you say that, Eddie?

Eddie: It looks like a football sweater to me because of the number and the stripes on the arm.

Teacher: Fine. Does everyone agree with Eddie?

Tom: His pants look like football pants.

Teacher: Does everyone agree with Tom? Good! Let's look at the boy's face. What can you tell me? Claudia.

Claudia: He looks like he might be mad or unhappy.

Teacher: Everybody look at the boy. Do you agree with Claudia?

[1] Obviously Bill has contributed labels that are irrelevant to the solution of the problem. Nevertheless the fact that he contributed is worthy of reward. Note that the teacher does not reinforce the information he offered. In fact, he draws attention to already mentioned information that is relevant.

(gets agreement) Fine. We said we saw a man. Tell me more about the man.

Tom: The man is smoking a pipe and he's raking leaves.

Teacher: Yes, he's raking leaves. What is he raking the leaves with?

(Note that the teacher does not reinforce the response "the man is smoking a pipe" since this is irrelevant to the solution of the problem.)

Tom: A rake.

Teacher: Does everyone see the rake? Tom, come up here and point out the rake to everyone. Good for you.

You said you saw a football. Tell me something about the football.

Marcia: The football is up on the side of the garage in the eave.

Teacher: Does everyone agree with Marcia?

(Teacher singles out student who makes limited responses.)

Robert, do you agree with Marcia? Where did she say the football was?

Robert: On the garage.

Teacher: Yes, but where on the garage? Marcia, tell us again where the football is.

Marcia: It is lying in the eave on the side of the garage.

Teacher: Can you say that, Robert?

Robert: (Repeats Marcia's statement)

Teacher: Good for you. Now, we said we saw the trellis. Who can tell me something about the trellis?

Eddie: The trellis is on the side of the garage near the football. It has vines growing on it.

Teacher: That's excellent Eddie. Can anyone add anything to that?

Claudia: It looks to me like the trellis is partly in the flowerbed.

Teacher: Here, Claudia, take the picture and show us what you mean. (Claudia points to the base of the trellis and flowerbed surrounding it. The class confirms her observation.)

Teacher: Someone said he saw a car. Who can tell us something about the car?

Marcia: The car looks like it's parked because I can't see anybody in it. It looks like it's just sitting in the driveway.

Teacher: Does everyone agree with Marcia? Good.

(The teacher estimates that the students have identified the salient elements in the stimulus picture and feels that some of them may be ready to put all of the data together and arrive at an inference. To facilitate this, the teacher will ask the students to associate the elements in the stimulus picture by reviewing in their own minds the labels and details that they have just discussed.)

Teacher: Now, let's all take another good look at the picture. Try to remember how we described the people and things that

we named and let's see if someone can give us an idea of what has happened. Tom, your hand was up.

Tom: It looks to me like the boy was going to play football and he was throwing the ball up in the air or kicking it and it went up on the garage roof and rolled into the eave.

Eddie: Maybe the boy and the man were playing catch with the football and the man threw it too far and it got stuck in the eave.

Teacher: (Given the inferences about what has occurred, it would be appropriate to test the quality of the inferences by reviewing what the children see as it relates to the inferences that were stated. This can be done by asking the students if they agree with each inference. By adroit questioning, the teacher can help the students refine their inferences. For example, with respect to the inference that the man and the boy were playing catch and the man threw the ball too high onto the roof, the teacher might ask, "If you were playing catch with someone and you threw the ball up so that it got stuck, what would you do, how would you act?" In this case, the teacher is drawing on the experiences of the students to have them recall that often a person who creates a problem assumes some responsibility for helping to solve it. Having, in this way, reduced the inferences to the more plausible ones by asking the students to draw upon their past experiences, the teacher is ready to ask for a second level of information; namely, a statement of the problem.)

Teacher: Well, we all agree that the boy threw the football up on the roof by himself or some other boys came along and took it away from him and threw it up. What do you think his problem is? Does it look to you as though he is going home to get a sandwich? What else do you think is troubling him? Tom, can you tell us?

Tom: It seems to me that he wants to get the ball down.

Teacher: Good, Tom. What do you think, Marcia?

Marcia: I think so too. If it was me, I would want my ball back.

Given the teacher's objective, namely to help the students to make inferences, this is as far as the teacher might go in this lesson. It is important to note that, throughout the lesson, the teacher did not provide answers nor did he verify all of the students' responses himself. Instead, he shared this activity with students, sometimes individually and sometimes as a group. The teacher limited his role to calling the attention to various elements in the stimulus picutre but left it to the students to state the problem. For example, when the students overlooked the affective message in the boy's face, the teacher directed their attention to his face without giving clues about his expression or the meaning of the expression within the context of the problem as a whole. In

the case of the inappropriate inference about the role of the man in creating the problem; the teacher called upon the students' experiences to help them see the inappropriateness of the inference.

The lessons that follow, as the teacher pursues his earlier stated objective, would be to have the students (a) recall the statement of the problem, and go back to labeling and detailing; (b) quickly review who and what was involved, and what happened; and (c) restate the problem. At that point, the teacher would be ready to move into the next step, predicting and verifying and, from there, to generalizing activities.

We indicated earlier that the teacher of the intermediate class assumes that her students have the necessary language to proceed with the lesson. She feels that these students don't need to spend time labeling and detailing the picture. The penalty for overestimating the abilities of students is not that great. What follows is a more or less typical result when the teacher has overestimated the students' abilities.

INTERMEDIATE LEVEL LESSON

Teacher Let's all take a good look at this picture. (Pause) Who can tell us what has happened in the picture?

Ralph The boy's father has asked him to help rake the lawn and the boy doesn't want to. (This is the only response the teacher can evoke from the class.)

Teacher. All right, let's see if Ralph is correct. Let's take another good long look at the picture and let's see if we can name all of the things that we see in it.

(The teacher is not getting the kinds of responses that allow her to involve students in the inferring step productively. Therefore, she has backtracked to the labeling and detailing stages which we described with the primary class. All that was lost were the few moments it took to attempt to draw an inference from the students. The transition from the inference step back to the earlier steps was accomplished quickly and smoothly. Now, let's take an example where the teacher's estimate of the students' abilities was more accurate.)

Teacher. Let's all look at this picture and when you think you know what has happened, raise your hand. (At this point, the teacher can test her assumption that the student has sufficient language and experience to enter this transaction on the inferring step. One way to do this is to call upon students who are among the least fluent and who in previous lessons, were among the last to move from the detailing to the inferring step. At least at the beginning, the teacher can

assume that if those bringing up the rear are able to respond correctly, the probability is high that the more competent students can respond correctly.)

Teacher: Robert, your hand was up; tell us what you think is happening here.

Robert: The boy is on his way home and he looked up and saw the football in the cave.

Teacher: Does that sound possible to everyone? Go ahead, Robert, and tell us what you think is happening.

Robert: He sees the football and he wants it and now he's wondering how he's going to get it down.

Teacher: Fine. Does everyone agree with Robert? Does anyone have a different opinion? Charles?

Charles: I think that the football is his and he was walking along after football practice throwing the ball up in the air and it landed up in the cave.

Teacher: OK, Charles. (The teacher now wants to check the function of labeling and detailing in Charles' inference.) What is there in the picture that leads you to believe he is coming home from football practice and that he threw his ball up in the air so that it landed in the cave?

Charles: Well, he's wearing a football uniform. He's wearing a football sweater and by the way his shoulders look he may still have his shoulder pads on. The pants look more like football pants than anything that we wear in school.

Teacher: How many of you feel that Charles is correct? All right, go ahead Charles, what else is happening?

Charles: I think he's unhappy because he wants to get the ball down and he doesn't see anything to get it down with.

Teacher: Good. Robert and Charles have different ideas about what has happened. But they do agree on something. Can you tell me what that is? (At this point, in order to involve the rest of the students, the teacher may poll each of the students to find out if they see the point of agreement.)-Henry, what do you think they agree on?

Henry: They both said that the boy wants to get the ball down.

Teacher Very good, Henry. Do we all agree on that point? (The teacher then asks each child to restate the issue.)

Teacher: Charles said that the boy looks unhappy. Why do you think the boy looks so unhappy?

Mabel: The ball is too high for him to reach.

Teacher: What would he need to get the ball down safely, easily, and quickly?

Mabel: A ladder.

Teacher: Do you see a ladder?

Mabel: No, I don't.

Teacher: That's good, Mabel. (Polls the class again to be sure that Mabel's response makes sense to them.) Since we agree

that a ladder would be the most help in getting the ball down and since we have no ladder, is there anything you see that the boy might use as a substitute in order to get the ball down? (With this question the teacher is leading the students into the predicting-verifying step.)

Marvin: He could climb up on the trellis and reach the ball.

Teacher: OK. How many feel that would be a good way to solve the problem?

Elinor: He could stand on the car and reach the football from there.

Teacher: All right. (Polls the class to see how many agree with this solution.) Any other suggestions? Carl.

Carl: He could ask the man if he could borrow his rake and poke the football out of the eave.

Teacher: OK, Carl, does anybody else have a suggestion? (Pauses) All right, no other suggestions. Now, who can tell us all of the ways he might get the ball down.

Robert: He could climb up the trellis, or he could stand on the car, or he could borrow the man's rake and poke it down.

Teacher: Very good. Now let's see which is the best way to solve the problem. (At this point, the teacher takes the class back to the labeling and detailing steps.) Look at the trellis and look at the boy and tell us something about the trellis. What do we have to know about the trellis before the boy climbs on it? Is it strong enough to hold him? What will happen if it is not? (The teacher pursues this tack with each of the students' recommendations, guiding the class to make inferences about the solutions offered in order to arrive at the best solution.)

Teacher: We've agreed that the trellis may break under the boy's weight and that the car is too far from the garage. What is left?

Robert: The boy can ask the man if he can borrow the rake.

Teacher: All right, let us see if we have been correct. (Displays verification picture, Figure 2.) What do you see?

Thomas: He borrowed the rake and is getting the ball down.

Teacher: Now who can put all we talked about into one story that ends with the boy getting his ball back. (Again, the teacher gives priority to the less-verbal members of the class but reserves the right to call on the more advanced students for support.) Carl?

Carl: (Usually with some help from others.) The boy was playing with his football and it landed in the eave. He wanted to get it down so he borrowed the man's rake and poked it out of the eave.

Teacher: Good for you Carl. But did you leave something out? (Carl does not answer. Teacher addresses same question to



FIGURE 2. Verification Picture.

class. Indications are that they have forgotten the fact of the absent ladder.)

Teacher Why did the boy have to use the rake? What is missing in the picture that would have made it much easier. For what did the boy substitute the rake?

Eleanor: It would have been easier if he had a ladder.

Teacher Good. So the rake was a substitute for . . . (pauses to encourage class to complete the statement).

Class A ladder

Teacher (Moves class into generalizing step.) Who can tell us why the trellis was not a good substitute for a ladder?

Robert Because it might break and the boy might fall and hurt himself.

Teacher: Okay. What should we keep in mind whenever we have to substitute something we need but do not have? Can someone tell me a rule? (Our experiences plus the data from the CASS and THINK indicate that this is a difficult task for younger students. Further, the data indicate that more than one problem solving experience is necessary before rules or principles begin to emerge. Nevertheless, it is a logical step following problem solving and should be pursued each time.)

Eleanor: Whenever we need to use a substitute, we should be sure that it will not break or hurt anyone.

Our purpose is going into such detail in both problem solving lessons is to underscore the flexibility inherent in the Logical Inductive strategy. Two different entry points were illustrated: the labeling step for one group, the inferring step for another. Where to initiate the strategy is influenced by the teacher's estimate of the competence of the class. If the teacher overestimates, a step or two back is indicated and can be accomplished quickly. If the teacher underestimates, e.g., asks for labels and gets combined labels and details and some inferences, he or she can move quickly to the next step.

Another reason for going into such detail is to demonstrate the role of the teacher as provoker, guider and occasionally, confirmer. There is great leeway for the type of involvement that teachers choose. To put it another way, teachers can be themselves. The overriding consideration, however, is that at no time does the teacher give an answer.

These simulated lessons also show some of the diagnostic aspects of Logical Inductive teaching. At the labeling and detailing steps, the teacher can observe where deficiencies in language or vocabulary are hampering certain students' progress. It is a teacher judgment how these deficiencies are handled. In some cases, the teacher makes note of which student or students are lacking words or the ability to describe objects, but goes on with the lesson by having those who are more competent help students who need it. Later the teacher includes the missing vocabulary or skill in a reading or language arts lesson. When it is clear to the teacher that too many of the students lack the necessary labeling and detailing skills, he or she can quickly convert the lesson into a language lesson. The lesson objective thus changes from problem solving to learning the new words that make problem solving progress possible.

While the simulated lessons suggest an even and productive flow of actions and interactions, keep in mind that they do not characterize typical first ventures into inductive teaching. The lessons more nearly reflect a setting where the Logical Inductive method has become an established teaching-learning framework. The teacher who is introducing this strategy should plan on having to overcome certain kinds of inertia. As pointed out earlier, teachers and students come to this type of interaction well indoctrinated in rote approaches to teaching and learning, where roles are nicely fixed. Some teachers and students will be reluctant to surrender the security of their pronounced role distinctions.

It is important to note, however, that all of the factors that stand in the way of immediate success are, to some degree, subject to change. While there are no guarantees, most teachers can learn to assume more than one role; in the course of the day, they can shift from a more autocratic role characterized by teaching situations that call for a rote or lecture approach to a more democratic role that is consistent with Logical Inductive transactions. Experiences with both the CASS and THINK, along with the studies on the teaching of tactics, show that

most students can move from dependency on the teacher to participation with the teacher and other students in problem solving activities.

The teacher has a powerful role in effecting positive change in students. Psychological hurdles can be overcome by maximizing the rewards for both participation (responding) and the quality of the response (being correct). Where deficiencies in language and/or the ability to make associations between facts and concepts stand in the way of reasoning, the teacher can focus on these deficiencies by providing either individual instruction or practice within the larger problem solving context.

We will always need to cope with the heterogeneity of student characteristics. Experience shows that any one class or group of mildly handicapped students will represent a range of intellectual and psychological functioning. Students will range from the relatively voluble to the cryptic, from the imaginative to the prosaic, and from the success striver to the failure avoider. Apart from chronological age and whatever else the teacher may know about the learning characteristics of each student, there are few reliable predictors of a student's potential to participate in problem solving activities. The THINK data show that IQ is not a trustworthy index in this respect.

In the event that the examples and the discussion that followed suggest ambiguity in the structure and sequence of Logical Inductive teaching, analogous to that found in Discovery and Guided Discovery strategies, a graphic description of the strategy is presented in Figure 3. In this schematic, the rectangles represent teacher actions and the ovals represent the actions of a student or group of students.

Here we can see that the Logical Inductive strategy presents options for the teacher. It offers flexibility as well as structure. For example, having identified the lesson objective, the teacher can enter the system at any rectangle, based on the readiness of the students to do so. If the relevant responses are not forthcoming, the teacher can revert to an earlier step in the system. To illustrate, let us say that having specified the lesson objective, the teacher asks a question designed to elicit labels, e.g., "Who can name the things we can see in the picture?" (See Step 1). The students do not respond. The teacher is justified in assuming either that (a) he or she does not have their attention or (b) they are attending, but lack the ability to name what they see. If the problem is one of attending, the teacher corrects the situation by making sure that students' attention is focused appropriately. If, on the other hand, the teacher overestimated the abilities of the students, he or she can abort the lesson, restate the objective (in this case, to learn the names of the pictured objects), and go on from that point.

At a more advanced step, the teacher's options are equally open. For example, in the second lesson simulation the teacher entered the process at the inference step (see Step 3). Most of the inferences were relevant except for Eddie's. He speculated that the man raking the leaves had been playing catch with the boy and threw the football onto the roof. At this point, the teacher could stop the forward progress of the

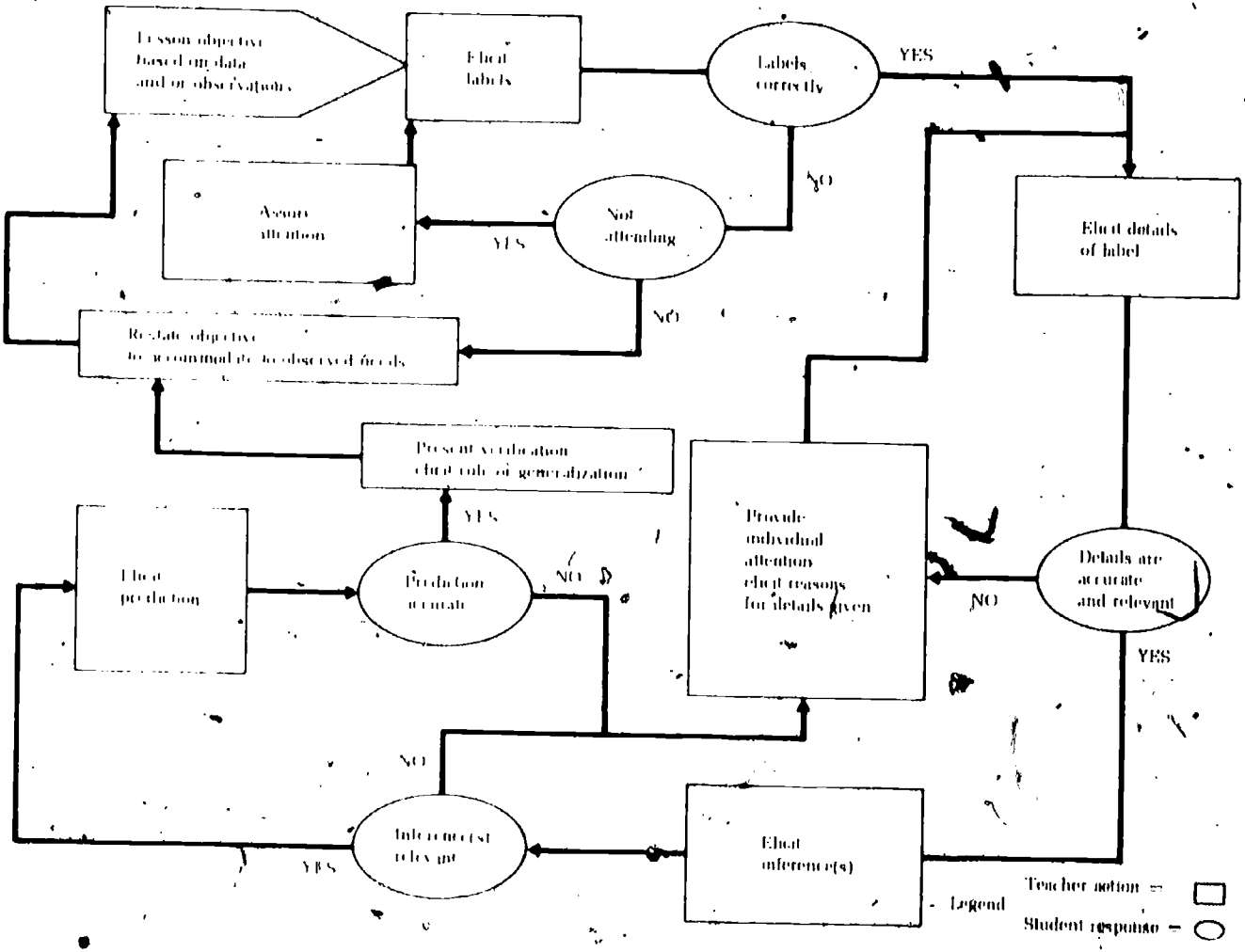


FIGURE 3. Inductive Problem Solving Sequence.

class in order to ask Eddie what details in the picture led him to his inference. It would also be appropriate for the teacher to help Eddie profit from experience with a question such as, "If you were the man and you knew that it was your fault that the football was stuck in the cave, would you be raking leaves? What would you do?" By drawing on the evidence in the picture, along with a generalized appeal to fair play, the teacher helps Eddie and the class dispose of a distracting inference so that they can move ahead to the solution of the problem.

At the end of the cycle, following the verification of the proposed solution, the teacher provides the opportunity for students to evolve a statement of a rule or principle relative to the problem, and the class of problems, just solved (see Step 5). Whether or not a generalization is stated, the teacher then moves on to the next objective and the process continues.

SUMMARY

There are three objectives associated with teaching by way of the Logical Inductive strategy. First, there is the universal objective of increasing the knowledge of mildly retarded students. Second, there is the objective of teaching in such a way that students learn a strategy that allows them to capitalize on their knowledge in the course of reasoning the solutions to problems. Finally, there is the objective of having students acquire feelings about themselves that will encourage them to solve problems independently.

The attainment of these objectives requires more than simply implementing certain teaching techniques or using particular teaching materials. It requires that the classroom be a place where teachers and students feel a unity of purpose and are able to share both successes and failures. This is not to say that roles need to be blurred or that responsibilities need to be ignored or surrendered. Rather, with full recognition of roles and responsibilities, there is nevertheless a shared feeling that "we're all on the same team."

Within this context, teacher planning can be directed toward achieving the second and third objectives. The content of learning needs to be relevant to both the immediate and long range maturational needs of students. Teacher judgment prevails in making decisions about setting priorities and sequencing content. Keeping the goals and objectives of education in mind provides a framework for decision making that lends both credibility and consistency to planning.

Once the content of instruction has been identified, knowledge of students' abilities and habilities is essential in helping the teacher to determine where to initiate the strategy with students and how to plan the amount of content that will be part of each activity or lesson.

Along with knowing what the content of instruction will be, and what the characteristics of the learners are, it is equally important to know how to manage the learning process using the Logical Inductive strategy. Teachers need to know the process thoroughly so that, step

by step, they can help students move toward solving problems and learning the necessary rules and principles to function productively after they reach school leaving age. If the teacher is not well organized, the steps in problem solving will be random and, in some cases, can defeat the purposes of the instruction.

In the course of implementing the Logical Inductive strategy, patience and insight are important teacher attributes. Some students will find it hard to believe that the teacher is sincere in believing that they are competent to share problem solving ventures. Students will need recurring experiences if they are to be convinced of the teacher's sincerity. Some students, although ready and willing to participate, may lack some of the basic knowledge required for involvement. The teacher has to take the time to help them garn the necessary background. The temptation to take shortcuts is present under both sets of conditions; it is much easier to "tell" than it is to ask key questions.

Of course, since the Logical Inductive strategy is developmental, achieving the desired end -- the generalization -- is certainly the most difficult step. But there should be some comfort in knowing that, as difficult as it is to achieve, once gained it opens up a broader range of problem solving for students and increases the possibility of their garning an important measure of independence.

Finally, the fact that the content of instruction is, from the start, abstract means that there cannot be extended gaps in instruction. Implementing the Logical Inductive strategy needs to be a day by day experience for teacher and students. The learning of abstract rules and principles is an emerging phenomenon. They emerge as an outcome of planned, structured, and frequent experiences. There is no substitute for continual practice if problem solving abilities are to develop and to be enhanced as part of the mildly handicapped student's instructional program.

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